Chapter 16: Partial Chronology of Accidents, Incidents, and Events at LANL

An important part of the review of historical records concerning Los Alamos operations focused on the review of records of the Health Division and other records that include descriptions of accidents or incidents that had potential association with off-site releases or health effects. Some of the incidents of interest include chemical releases, fires, explosions, radiation exposures to workers, and other notable accidents that occurred at Los Alamos. The incidents that are potentially relevant to off-site releases or health effects are of particular importance.

Based on review of reports and items of correspondence assembled by the LAHDRA team, a partial chronology of accidents, incidents, and events at Los Alamos was compiled. The information presented in Table 16-1 is a partial chronology because the information was collected from many sources, and it is likely that not all reports documenting accidents and incidents were found. Minor worker contamination incidents were not included. Spills of small amounts of low toxicity materials to a solid surface that was easily cleaned up were not included. The quantity and type of contamination released is reported when available.

First, Health Division reports in the database were reviewed for incidents of interest. Next, the LAHDRA DocSleuth database was searched for selected keywords (such as health report, quarterly, monthly H Division progress reports) to obtain additional documents to review. The additional documents identified via that keywords search were reviewed and incidents of interest were recorded. Next, the search was expanded to include documents relevant to criticality incidents, explosions, and RaLa shots.

In Table 16-1, the first column lists the stated date of the incident or event, or an estimated date based on the date of the source document.

The second column contains a brief description of the incident or event. Any qualitative descriptions or impressions given are those of the original document's authors, as are any release quantities or off-site measurements. The original document text can be viewed if questions arise or additional information or context is desired.

The third column in the table contains a categorization of each event. Each event was categorized based on the incident type and the potential for off-site release or possible adverse health effects. The categories used were as follows:

- Accident – An incident not involving radioactive or dangerous material
- Air Release – An incident that involved the release of air contamination
- Criticality – An event in which a mass of radioactive material went “critical”
- Equipment Malfunction – An incident that was the result of equipment failure
- Explosion – An incident that involved an explosion
- Fire – An incident that involved fire
- Liquid Release – An incident that involved the release of liquid contamination
- RaLa Shot – Explosive test event involving radioactive lanthanum
- User Error – Event involving a human error
- Contamination Event – Additional unclassifiable contamination events

The fourth column contains the LAHDRA Repository Number of the source document. In some cases, documents contain so many pages that their image files were broken up into pieces to facilitate downloading. In these cases, the Repository Number may be followed by a letter, for example 338f for the sixth part of a large document having at least six PDF image files.

The fifth and final column in Table 16-1 contains the page number at which the description of the described incident or event begins. This is the page number in the PDF file, which in many cases differs from the page number shown on the original document page, as cover pages and early pages of a printed document are often not numbered, or in some cases not all pages from the source document were requested by the LAHDRA document analysts or released by LANL.

Over 30,000 pages in over 500 documents were reviewed in the preparation of the chronology of accidents and incidents, with those documents including:

- Contamination incident reports
- Incident report investigation files
- Miscellaneous laboratory incident memorandums
- Radiation occurrence reports
- A review of criticality accidents
- A survey of liquid waste management problems at LASL
- Monthly and annual reports of DP West Site operations
- Annual reports of the Health Division
- Health physics/radiation protection quarterly reports
- Incidents and accidents involving explosives at Los Alamos National Laboratory
- Reports of the Bayo Canyon/Radioactive Lanthanum (RaLa) Program
- Airborne Contamination Annual Summaries
- Summaries of LASL Health Hazards

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
9/21/1944	RaLa shot # 1 took place on 9/21/1944 at ~1610 hours. The shot involved ~25 to 60 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
10/4/1944	RaLa shot # 2 took place on 10/4/1944 at 1937 hours. The shot involved 120 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
10/14/1944	RaLa shot # 3 took place on 10/14/1944 at 1651 hours. The shot involved 60 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
10/26/1944	RaLa shot # 4 took place on 10/26/1944 at 1540 hours. The shot involved 185 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
11/3/1944	RaLa shot # 5 took place on 11/3/1944 at ~1645 hours. The shot involved 113 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa at dwelling T-846, near the present corner of Rim and Canyon Roads, which was the nearest habitation to the firing point. The purpose was apparently to detect any radioactivity that might be carried to the Los Alamos town site, although whether or not Los Alamos was downwind was not recorded. The air samplers were run during each shot and for some time after the shot was fired. The results of each sample were negative, indicating that no radioactivity from these shots reached the town site.	RaLa Shot	2	all
12/1/1944	RaLa shot # 6 took place on 12/1/1944 at 1630 hours. The shot involved 280 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
12/10/1944	RaLa shot # 7 took place on 12/10/1944 at 635 hours. The shot involved 90 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
12/14/1944	RaLa shot # 8 took place on 12/14/1944 at 2158 hours. The shot involved 110 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
12/20/1944	RaLa shot # 9 took place on 12/20/1944 at 1445 hours. The shot involved 82 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
12/28/1944	RaLa shot # 10 took place on 12/28/1944 at 1535 hours. The shot involved 47 Ci of RaLa with an explosive charge of 20 to 100 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
2/7/1945	RaLa shot # 11 took place on 2/7/1945 at 1310 hours. The shot involved 220 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
2/11/1945	On February 11, 1945 there was a criticality incident involving UH_3 pressed in styrex. The assembly went prompt critical during the dropping of a slug of the active material through a vertical hole. The UH3-styrex cubes were swollen and blistered from the heat of the reaction. ~6 x 10^{15} total fissions were involved.	Criticality	6206	all
2/13/1945	RaLa shot # 12 took place on 2/13/1945 at 1945 hours. The shot involved 240 Ci of RaLa with an explosive charge of 201 to 350 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
2/18/1945	RaLa shot # 13 took place on 2/18/1945 at 1626 hours. The shot involved 240 Ci of RaLa with an explosive charge of 601 to 750 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
2/24/1945	RaLa shot # 14 took place on 2/24/1945 at 1644 hours. The shot involved 135 Ci of RaLa with an explosive charge of 601 to 750 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
3/3/1945	RaLa shot # 15 took place on 3/3/1945 at 2226 hours. The shot involved 70 Ci of RaLa with an explosive charge of 601 to 750 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.	RaLa Shot	2	all
4/1/1945	RaLa shot # 16 took place on 4/1/1945 at 1645 hours. The shot involved 290 Ci of RaLa with an explosive charge of 601 to 750 lbs. An air sampler was set up at the edge of Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative. The date for one of the air samples was recorded as March 31, 1945; however, no shot was fired on that date. Since shot #16 was fired on April 1,1945, the March 31,1945, date is believed to be in error.	RaLa Shot	2	all
4/9/1945	RaLa shot # 17 took place on 4/9/1945 at 120 hours. The shot involved 530 Ci of RaLa with an explosive charge of 201 to 350 lbs. The cloud tracked toward the ESE. An air sampler was run on Los Alamos Mesa (location unknown) during the shot and for 8 hours afterward. No activity was found.	RaLa Shot	2	all

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
4/15/1945	RaLa shot # 18 took place on 4/15/1945 at 2035 hours. The shot involved 215 Ci of RaLa with an explosive charge of 201 to 350 lbs. The cloud tracked toward the ESE. An air sampler was run at Technical Area 1 (TA-1, the main technical area) for 24 hours to check for contamination. A reading of 50 counts per minute (cpm) gamma radiation was found. "This was the first time that any airborne contamination [associated with Bayo Canyon] was picked up on the mesa."	RaLa Shot	2	all
4/20/1945	RaLa shot # 19 took place on 4/20/1945 at 1841 hours. The shot involved 220 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/26/1945	RaLa shot # 20 took place on 4/26/1945 at 2143 hours. The shot involved 150 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
5/11/1945	On May 11, 1945 an accident occurred in Room B2 of Gamma Building. A rotating shield struck a piece of Po metal, sending contamination through out the lab.	Contam. Event	3496	8
5/22/1945	RaLa shot # 21 took place on 5/22/1945 at 1547 hours. The shot involved 620 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/26/1945	RaLa shot # 22 took place on 5/26/1945 at 1700 hours. The shot involved 450 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/30/1945	RaLa shot # 23 took place on 5/30/1945 at 1500 hours. The shot involved 342 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
6/4/1945	RaLa shot # 24 took place on 6/4/1945 at 1630 hours. The shot involved 900 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
6/6/1945	On June 6, 1945 there was a criticality incident involving 35.4 kg U-235 in 1/2-inch cubes. The pseudo sphere went critical during water seeping between the blocks. ~3x 10^{16} total fissions were involved.	Criticality	6206	all
6/8/1945	RaLa shot # 25 took place on 6/8/1945 at 1545 hours. The shot involved 795 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/13/1945	RaLa shot # 26 took place on 6/13/1945 at 1535 hours. The shot involved 569 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
6/16/1945	RaLa shot # 27 took place on 6/16/1945 at 1508 hours. The shot involved 367 Ci of RaLa with an explosive charge of 201 to 350 lbs. A high-capacity air sampler was run at the edge of Los Alamos Mesa in front of civilian dwelling T-843 (probably T-846). Thirteen thousand five hundred (13,500) liters of air were sampled, and the beta plus gamma activity on the filter was less than 10 cpm (background). Another sampler was set up at TA-1 in front of Q Building. Results were also negative	RaLa Shot	2	all
6/22/1945	RaLa shot # 28 took place on 6/22/1945 at 1530 hours. The shot involved 1060 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/26/1945	RaLa shot # 29 took place on 6/26/1945 at 1724 hours. The shot involved 737 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/29/1945	RaLa shot # 30 took place on 6/29/1945 at 1700 hours. The shot involved 393 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/6/1945	RaLa shot # 31 took place on 7/6/1945 at 1718 hours. The shot involved 343 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/14/1945	RaLa shot # 32 took place on 7/14/1945 at 1715 hours. The shot involved 190 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
7/16/1945	**The world's first nuclear explosion took place at the Trinity site in southern New Mexico at 5:29 a.m.**		various	
8/3/1945	RaLa shot # 33 took place on 8/3/1945 at 2145 hours. The shot involved 471 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
8/6/1945	**Little Boy gun type atomic bomb dropped on Hiroshima, Japan.**			
8/9/1945	**Fat Man implosion type atomic bomb dropped on Nagasaki, Japan.**			
8/10/1945	RaLa shot # 34 took place on 8/10/1945 at 1531 hours. The shot involved 240 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
8/15/1945	RaLa shot # 35 took place on 8/15/1945 at 1530 hours. The shot involved 168 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
8/21/1945	On August 21, 1945 there was a criticality incident involving 6.2 kg gamma-phase Pu. An experimenter was hand stacking tungsten carbide blocks around a Pu mass. The experimenter accidentally dropped a block allowing the Pu to go critical. 1 death and 1 injury resulted from the accident. ~10^{16} total fissions were involved.	Criticality	6206	all
8/24/1945	RaLa shot # 36 took place on 8/24/1945 at 1556 hours. The shot involved 1200 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/1/1945	RaLa shot # 37 took place on 9/1/1945 at 1620 hours. The shot involved 1050 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/8/1945	RaLa shot # 38 took place on 9/8/1945 at 1740 hours. The shot involved 628 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all

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9/13/1945	RaLa shot # 39 took place on 9/13/1945 at 1615 hours. The shot involved 440 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
9/20/1945	RaLa shot # 40 took place on 9/20/1945 at 1415 hours. The shot involved 380 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
9/25/1945	RaLa shot # 41 took place on 9/25/1945 at 1740 hours. The shot involved 1291 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/26/1945	There was a fire in the contaminated pit September 26, 1945. Contamination was found on the fence surrounding the area and on the guard tower next to the dump.	Fire	4525	3-5
10/1/1945	RaLa shot # 42 took place on 10/1/1945 at 1716 hours. The shot involved 772 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
10/6/1945	RaLa shot # 43 took place on 10/6/1945 at 1605 hours. The shot involved 446 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
10/12/1945	RaLa shot # 44 took place on 10/12/1945 at 1620 hours. The shot involved 516 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
11/28/1945	On November 28, 1945 in Room 76 of DP Site a worker noticed that a container of Po had leaked. The room was decontaminated.	Liquid Release	4525	2
12/14/1945	RaLa shot # 45 took place on 12/14/1945 at 1655 hours. The shot involved 345 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
12/28/1945	RaLa shot # 46 took place on 12/28/1945 at 1620 hours. The shot involved 1340 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/4/1946	RaLa shot # 47 took place on 1/4/1946 at 1628 hours. The shot involved 954 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/11/1946	RaLa shot # 48 took place on 1/11/1946 at 1600 hours. The shot involved 647 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/17/1946	RaLa shot # 49 took place on 1/17/1946 at 1530 hours. The shot involved 459 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
1/24/1946	RaLa shot # 50 took place on 1/24/1946 at 1610 hours. The shot involved 1712 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W. The maximum radiation measured at distance (mR/h) was 0.046 mR/h at 2 miles. The cloud from the shot drifted toward TA-1. Gamma radiation measurements throughout the technical area ranged from 0.028 to 0.046 mR/h. Normal background is about 0.028 mR/h	RaLa Shot	2	all
1/31/1946	RaLa shot # 51 took place on 1/31/1946 at 1555 hours. The shot involved 1057 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
2/7/1946	RaLa shot # 52 took place on 2/7/1946 at 1537 hours. The shot involved 654 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
2/14/1946	RaLa shot # 53 took place on 2/14/1946 at 1602 hours. The shot involved 454 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
3/21/1946	RaLa shot # 54 took place on 3/21/1946 at 1520 hours. The shot involved 1034 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/28/1946	RaLa shot # 55 took place on 3/28/1946 at 1447 hours. The shot involved 848 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/12/1946	RaLa shot # 56 took place on 4/12/1946 at 1555 hours. The shot involved 315 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
4/15/1946	There was a tuballoy fire in the Tech area on April 15, 1946. Firemen were exposed directly to tuballoy smoke without protective equipment.	Fire	4285	11
4/25/1946	RaLa shot # 57 took place on 4/25/1946 at 1520 hours. The shot involved 1324 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/2/1946	RaLa shot # 58 took place on 5/2/1946 at 1500 hours. The shot involved 890 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/3/1946	There was a explosion in a drybox in Room 107 of D Building on May 3, 1946. The room and adjoining hallway were contaminated.	Explosion	4526	2
5/9/1946	RaLa shot # 59 took place on 5/9/1946 at 1440 hours. The shot involved 600 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
5/16/1946	RaLa shot # 60 took place on 5/16/1946 at 1535 hours. The shot involved 279 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
5/21/1946	On May 21, 1946 there was a criticality incident involving 6.2 kg of delta-phase Pu. An experimenter was holding two hemispheres of Pu apart with a screw driver as a demonstration to a group. When the screw driver slipped, it allowed the spheres to come together to form a critical mass. 1 death and 7 injuries resulted from the accident. ~$3X10^{15}$ total fissions were involved.	Criticality	6206	all
5/23/1946	RaLa shot # 61 took place on 5/23/1946 at 1440 hours. The shot involved 1274 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/29/1946	RaLa shot # 62 took place on 5/29/1946 at 1450 hours. The shot involved 931 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/6/1946	RaLa shot # 63 took place on 6/6/1946 at 1445 hours. The shot involved 539 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/27/1946	RaLa shot # 64 took place on 6/27/1946 at 1440 hours. The shot involved 1494 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/3/1946	RaLa shot # 65 took place on 7/3/1946 at 1625 hours. The shot involved 976 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/11/1946	Pu metal turnings caught fire in a drybox in Room 317 on July 11, 1946. The room was highly contaminated.	Fire	4526	4
7/11/1946	RaLa shot # 66 took place on 7/11/1946 at 1423 hours. The shot involved 702 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
7/18/1946	RaLa shot # 67 took place on 7/18/1946 at 1530 hours. The shot involved 516 Ci of RaLa with an explosive charge of 201 to 350 lbs.	RaLa Shot	2	all
8/1/1946	The first fatality involving energetic materials at Los Alamos was at the Omega-West Reactor Site in August 1946. Thre employees mixed potassium chlorate, sugar, magnesium turnings, and red phosphorous. One person died when the mixture ignited, and two others were injured.	Explosion	6203	9
8/28/1946	RaLa shot # 68 took place on 8/28/1946 at 2245 hours. The shot involved 1026 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
11/15/1946	There was a fire in the contaminated dump on November 15, 1946.	Fire	4526	1
12/19/1946	RaLa shot # 69 took place on 12/19/1946 at 1640 hours. The shot involved 1261 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/27/1946	RaLa shot # 70 took place on 12/27/1946 at 2202 hours. The shot involved 610 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/3/1947	RaLa shot # 71 took place on 1/3/1947 at 1920 hours. The shot involved 467 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/16/1947	On January 16, 1947 a worker cutting $Pu(NO_3)_4$ spilled approximately 70 mg of solution on their pants and the floor of D-146.	User Error	3482	2
1/23/1947	On January 23, 1947 a worker with a sledge hammer hit a 5 gallon bottle containing plutonium residue releasing approximately 30 mg of Pu in the basement of D Building. The ground was dug up and buried in the waste disposal pit.	User Error	3482	4
3/10/1947	RaLa shot # 72 took place on 3/10/1947 at 2200 hours. The shot involved 570 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/14/1947	RaLa shot # 73 took place on 3/14/1947 at 1758 hours. The shot involved 720 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/19/1947	RaLa shot # 74 took place on 3/19/1947 at 1952 hours. The shot involved 630 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/11/1947	RaLa shot # 75 took place on 4/11/1947 at 140 hours. The shot involved 480 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/16/1947	RaLa shot # 76 took place on 4/16/1947 at 1832 hours. The shot involved 640 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/6/1947	RaLa shot # 77 took place on 5/6/1947 at 1540 hours. The shot involved 1341 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/13/1947	RaLa shot # 78 took place on 5/13/1947 at 1655 hours. The shot involved 1141 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/21/1947	RaLa shot # 79 took place on 5/21/1947 at 1926 hours. The shot involved 574 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/18/1947	RaLa shot # 80 took place on 6/18/1947 at 1438 hours. The shot involved 170 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/25/1947	RaLa shot # 81 took place on 6/25/1947 at 1319 hours. The shot involved 1290 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/2/1947	RaLa shot # 82 took place on 7/2/1947 at 1800 hours. The shot involved 1320 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
7/10/1947	RaLa shot # 83 took place on 7/10/1947 at 1703 hours. The shot involved 851 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
7/30/1947	RaLa shot # 84 took place on 7/30/1947 at 1850 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
8/6/1947	RaLa shot # 85 took place on 8/6/1947 at 1706 hours. The shot involved 700 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
8/13/1947	RaLa shot # 86 took place on 8/13/1947 at 1545 hours. The shot involved 680 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
8/27/1947	RaLa shot # 87 took place on 8/27/1947 at 2022 hours. The shot involved 1610 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/4/1947	RaLa shot # 88 took place on 9/4/1947 at 1655 hours. The shot involved 925 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/11/1947	RaLa shot # 89 took place on 9/11/1947 at 1625 hours. The shot involved 670 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/18/1947	RaLa shot # 90 took place on 9/18/1947 at 1420 hours. The shot involved 438 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
10/22/1947	A fire was detected on October 22, 1947 in the contaminated dump. The results of monitoring during and after the fire reportedly indicated that there was no significant exposure to radioactive materials.	Fire	4285	8
10/29/1947	RaLa shot # 91 took place on 10/29/1947 at 1543 hours. The shot involved 1670 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all

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11/5/1947	RaLa shot # 92 took place on 11/5/1947 at 1522 hours. The shot involved 946 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
11/7/1947	On November 7, 1947 pressurized radioactive spray was released from a line of the peroxider unit contaminating one worker.	Equipment Malfunction	3482	11
11/12/1947	RaLa shot # 93 took place on 11/12/1947 at 1543 hours. The shot involved 730 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
11/27/1947	RaLa shot # 94 took place on 11/27/1947 at 1755 hours. The shot involved 720 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/3/1947	RaLa shot # 95 took place on 12/3/1947 at 1735 hours. The shot involved 1056 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/10/1947	RaLa shot # 96 took place on 12/10/1947 at 1816 hours. The shot involved 706 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/18/1947	RaLa shot # 97 took place on 12/18/1947 at 1529 hours. The shot involved 619 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
1/29/1948	RaLa shot # 98 took place on 1/29/1948 at 1436 hours. The shot involved 1240 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
2/5/1948	RaLa shot # 99 took place on 2/5/1948 at 1906 hours. The shot involved 1010 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
2/19/1948	RaLa shot # 100 took place on 2/19/1948 at 1459 hours. The shot involved 590 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
2/27/1948	RaLa shot # 101 took place on 2/27/1948 at 1440 hours. The shot involved 310 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/1/1948	RaLa shot # 102 took place on 4/1/1948 at 1630 hours. The shot involved 980 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/9/1948	RaLa shot # 103 took place on 4/9/1948 at 1517 hours. The shot involved 620 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/16/1948	RaLa shot # 104 took place on 4/16/1948 at 1455 hours. The shot involved 400 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
6/16/1948	On June 16, 1948 there was a fire in the drybox of Room D-115. The fire was believed to have been caused by spontaneous combustion of U-235 lathe turnings.	Fire	1184	65
8/4/1948	RaLa shot # 105 took place on 8/4/1948 at 1626 hours. The shot involved 590 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
8/12/1948	RaLa shot # 106 took place on 8/12/1948 at 1540 hours. The shot involved 771 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SW. No activity above background was measured in the vicinity of the airstrip (now Los Alamos Airport). The roads north and south of the airstrip were checked. A film badge planted at the east end of the airstrip had only 0.003 R exposure, which is close to the limit of sensitivity for this device.	RaLa Shot	2	all
8/19/1948	RaLa shot # 107 took place on 8/19/1948 at 1625 hours. The shot involved 547 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/10/1948	RaLa shot # 108 took place on 9/10/1948 at 1721 hours. The shot involved 1735 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/14/1948	On September 14, 1948 workers cleaned out a drybox in Room 126. The material was taken to the hood in Room 119 where it was accidentally released. The room was decontaminated the following day.	User Error	3485	7
9/21/1948	RaLa shot # 109 took place on 9/21/1948 at 1543 hours. The shot involved 1006 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/28/1948	RaLa shot # 110 took place on 9/28/1948 at 1538 hours. The shot involved 487 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
10/7/1948	RaLa shot # 111 took place on 10/7/1948 at 1410 hours. The shot involved 362 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
10/14/1948	RaLa shot # 112 took place on 10/14/1948 at 1442 hours. The shot involved 205 Ci of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
10/21/1948	RaLa shot # 113 took place on 10/21/1948 at 1411 hours. The shot involved 123 Ci of RaLa with an explosive charge of 20 to 100 lbs.	RaLa Shot	2	all

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
12/1/1948	RaLa shot # 114 took place at 1608 hours. The shot involved 480 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the south. H-1 leader T. N. White observed the cloud to drift a few points west of south and most of it appeared to settle down into Pueblo Canyon, just north of main hill road. White also saw a wisp go over Emilio Segre's old laboratory (East Gate Laboratory) at the extreme eastern end of Los Alamos Mesa. White went there with a radiation survey meter and was able to locate activity at the tip of the mesa. A few specks gave a reading that was close to the maximum with the beta shield open (20 mR/h). There was no activity a hundred feet or more to the west of the mesa tip. Following this observation, White expressed concern to D. Mueller, the leader of the Bayo Canyon experimenters, that it was undesirable to set off shots without regard to wind direction and velocity.	RaLa Shot	2	all
12/8/1948	RaLa shot # 115 took place on 12/8/1948 at 2039 hours. The shot involved 463 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
12/15/1948	RaLa shot # 116 took place on 12/15/1948 at 1345 hours. The shot involved 317 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E. The wind speed was 10 mph. The maximum radiation measured at distance was 0.76 mR/h at 0.25 miles.	RaLa Shot	2	all
1/25/1949	RaLa shot # 117 took place on 1/25/1949 at 405 hours. The shot involved 452 Curies of RaLa with an explosive charge of 351 to 600 lbs.	RaLa Shot	2	all
2/1/1949	RaLa shot # 118 took place on 2/1/1949 at 1630 hours. The shot involved 487 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/4/1949	RaLa shot # 119 took place on 3/4/1949 at 1359 hours. The shot involved 693 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/8/1949	RaLa shot # 120 took place on 3/8/1949 at 1413 hours. The shot involved 604 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
3/31/1949	RaLa shot # 121 took place on 3/31/1949 at 1647 hours. The shot involved 1096 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
4/20/1949	RaLa shot # 122 took place on 4/20/1949 at 1846 hours. The shot involved 422 Curies of RaLa with an explosive charge of 601 to 750 lbs. A monthly progress report of the Health Division stated, “The radioactive cloud from the Bayo shot of April 20 passed over and contaminated the area of the main gate to Los Alamos. The Fire Department washed off the most heavily contaminated section of the road shortly thereafter.” No survey report has been found.	RaLa Shot	2	all
4/27/1949	RaLa shot # 123 took place on 4/27/1949 at 2045 hours. The shot involved 1244 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/4/1949	RaLa shot # 124 took place on 5/4/1949 at 2045 hours. The shot involved 1740 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/11/1949	RaLa shot # 125 took place on 5/11/1949 at 1950 hours. The shot involved 1393 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
5/17/1949	RaLa shot # 126 took place on 5/17/1949 at 2030 hours. The shot involved 871 Curies of RaLa with an explosive charge of 601 to 750 lbs. A day after the last Bayo Canyon shot (#126) “activity was discovered at a point about two miles north of the Bayo firing site. The general background activity [meaning contamination] in this area was of the order of 1 mr/hr beta plus gamma ...” (presumed to be at waist height).	RaLa Shot	2	all
5/20/1949	RaLa shot # 127 took place at 1830 hours. The shot involved 588 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the ESE. The wind speed was 10 mph. The cloud from the shot crossed State Road 4 between Station 101 (a temporary guard gate at the access road to Bayo Canyon) and the McKee Trailer Camp on State Road 4. Roadblocks were established at the Main Gate and lower Bayo Canyon road junction with the main hill road. Following the shot, the blocked-off section of the road and a section running about 1 mi. east were monitored and found to be free of contamination; the roadblocks were removed. Shortly thereafter a second monitoring patrol discovered contamination on the road to the east of Frijoles Junction (the White Rock Y at the intersection of main hill road and State Road 4), which had been thought to be clean. Roadblocks were re-established at the Main Gate. The most heavily contaminated stretch of road ran about 0.75 miles east of Frijoles Junction. The highest readings were 5 to 10 mR/h 12 inches from the ground.	RaLa Shot	2	all

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
6/2/1949	RaLa shot # 128 took place at 1417 hours. The shot involved 1933 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the north. The wind speed was 12 mph. The maximum radiation measured at distance was 1.5 mR/h at 1.5 miles. "Flypaper and pans [adhesive fallout collectors] distributed in Guaje Canyon previous to the shot were collected approximately two hours afterwards and were found to have no contamination. The following afternoon, however, approximately 15 mr/hr beta and gamma background [assumed at 12 inches] was found in the region over which the cloud passed." Because "the meteorologist estimated that the cloud reached this position about five minutes after the shot," the conclusion can be reached that the flypaper and pans were not located in the main path of the fallout.	RaLa Shot	2	all
6/6/1949	RaLa shot # 129 took place at 2206 hours. The shot involved 1630 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SE. The maximum radiation measured at distance was 1.5 mR/h at 2.5 miles. Adverse weather continued until after the shot. "An attempt was made by Health Division personnel to postpone the shot until such time that conditions were more favorable, but the decision was made to continue." After the shot it became apparent that a portion of the main road to Los Alamos (SR 502) would become contaminated. Road blocks were placed at the west end of the airstrip, the junction of SR 4 and Sandia Canyon, and above Totavi Camp. Monitoring on the main road showed contamination from the pump house at the Bayo Canyon turnoff to 0.5 miles above Totavi, a distance of about 1.5 miles. The highest reading obtained was about 15 mR/h beta plus gamma at the main hill road and SR 4 junction. This measurement was taken at 12 inches above the road surface rather than at the usual 3 feet as was adopted later.	RaLa Shot	2	all
6/10/1949	RaLa shot # 130 took place on 6/10/1949 at 933 hours. The shot involved 1280 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NW. The wind speed was 6 mph. "Considerable effort was made by all persons involved to plan this particular operation so that the difficulties encountered in previous operations would not be present." Continuous weather predictions were done until after the shot. "The cloud drifted off in a northwesterly direction.... Although the main portion of the cloud did not pass over any of the previously placed trays and flypaper in Guaje Canyon, a small amount of background was found seven hours later on two of them located at one edge of the cloud path."	RaLa Shot	2	all
7/28/1949	RaLa shot # 131 took place on 7/28/1949 at 1204 hours. The shot involved 1387 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.	RaLa Shot	2	all
8/3/1949	RaLa shot # 132 took place on 8/3/1949 at 1258 hours. The shot involved 936 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.	RaLa Shot	2	all
8/9/1949	RaLa shot # 133 took place on 8/9/1949 at 957 hours. The shot involved 713 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.	RaLa Shot	2	all
8/18/1949	On June 27, 1949 there was a fire outside of TU Buildings. Fire resulted from the spontaneous combustion of TU shavings stored outside TU Building. Surrounding area was highly contaminated.	Fire	1184	169
8/31/1949	RaLa shot # 134 took place on 8/31/1949 at 1200 hours. The shot involved 715 Curies of RaLa with an explosive charge of 601 to 750 lbs.	RaLa Shot	2	all
9/14/1949	Rala shot # 135 took place on 9/14/1949 at 1202 hours. The shot involved 356 Curies of RaLa with an explosive charge of 601 to 750 lbs. Flypapers placed on North Ridge (the closest northern approach to Bayo Canyon, about 0.5 miles north, a little west, and 400 feet above of the firing site) about 50 paces apart read 3 to 4 mR/h at 1 inch with a closed-shield GM survey meter.	RaLa Shot	2	all
9/23/1949	RaLa shot # 136 took place on 9/23/1949 at 1018 hours. The shot involved 346 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SE. The wind speed was 8 mph. Nine flypapers placed on North Ridge read 0.15 to 1.0 mR/h at I inch with a closed-shield GM survey meter; the maximum reading was recorded 300 paces from the eastern-most station; the pattern appears to be skewed to the west.	RaLa Shot	2	all

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
10/19/1949	RaLa shot # 137 took place on 10/19/1949 at 1007 hours. The shot involved 1385 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE. The wind speed was 15-20 mph. Flypapers placed on North Ridge read from 0.1 to 0.3 mR/h at 1 inch, measured with a closed-shield GM survey meter. The maximum flypaper reading was recorded 150 paces west of the eastern edge of the array. The ground measured 0.07 mR/h near and in good agreement with one of the flypapers, which read 0.1 mR/h. The dose rate recorder at the same location reached 1.5 mR/h as the cloud passed. A survey made the next day in Rendija Canyon about a mile east of the Sportsman's Club showed a maximum of 0.07 mR/h.	RaLa Shot	2	all
11/2/1949	RaLa shot # 138 took place at 1205 hours. The shot involved 1614 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W. The maximum radiation measured at distance was 0.8 mR/h at 2.5 miles. T. Shipman reported “an abrupt and temporary shift in the wind ... resulted in blowing the cloud ... across the Technical Area [TA-1]. As far as health and safety are concerned, no significant levels of radiation have been found. There is, however, sufficient contamination so that the background in certain counting procedures may be disturbed.” “Demonstrable contamination was found as far away as Camp May, a distance often miles' [west], but at no place were levels of contamination found to be very high.” Levels of radiation were three times background at the Base Radio Station on North Mesa. The tip of Center Mesa read 0.6 mR/h; the Chapel Apartment area on Rose Street read 0.8 mR/h; Manhattan Loop read 0.3 to 0.4 mR/h; the peak at the main gate was 1.0 mR/h gamma (1.5 mR/h, beta plus gamma). Measurements made on North Ridge were all background.	RaLa Shot	2	all
11/8/1949	RaLa shot # 139 took place on 11/8/1949 at 1243 hours. The shot involved 1064 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 7-9 mph. The cloud moved west up canyon and then northeast, missing the North Ridge flypaper array. No record of radiation measurements in surrounding areas was found.	RaLa Shot	2	all
11/14/1949	On November 14, 1949 an accident occurred between two security trucks. One truck was carrying wooden crates of steel cylinders that contained plutonium. Only one wooden crate was damaged and no contamination occurred.	Accident	3484	7
12/1/1949	In December, 1949 there was a criticality incident involving ~1 kg ^{235}U UO_2 $(NO_3)_2$ in 13.6 liters water during the manual withdrawal of two poison control rods. $3.4x10^{16}$ total fissions were involved.	Criticality	6206	all
12/8/1949	RaLa shot # 140 took place on at 1532 hours. The shot involved 2635 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 8-12 mph. The maximum radiation measured at distance was 0.6 mR/h at 2 miles. Readings from the North Ridge flypapers ranged from background to 2.5 mR/h at 1 inch measured with a closed-shield GM survey meter. The maximum reading was found on the station 50 paces from the eastern end of the nine-station array. The Point Pluto (labeled 23) recorder showed cloud passage and the collected air sample was “3X normal = 0.015 mr/ hr.” At Point Claim, the cloud passed, and a sample read “0.6 mr/hr gammas only.” Guaje Canyon was monitored the next day and a maximum of 0.2 mR/h was found "opposite Pt. Claim." Also recorded are some "GMX-5 data giving 1.2 mr/hr in Rendija Canyon N of 12 and 0.5 mr/hr N of 10."	RaLa Shot	2	all
12/16/1949	RaLa shot # 141 took place at 1739 hours. The shot involved 1539 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NW. The wind speed was 2-3 mph. The maximum reading on flypaper on North Ridge read 1 mR/h at 1 inch, measured with a closed-shield GM survey meter. The cascade impactor at Point Claim showed most of the activity to be collected on the final (filter) stage, 0.7-micron particles if density 2.5 is assumed. Another handwritten description of the December 16 shot exists and has some valuable contemporary thinking comparing RaLa with radium and some dimensional help. But, again, all discussion was aimed, as were the previous flypaper measurements, at showing whether providing an asphalt pad under the shots would reduce fallout. It apparently did. The writer calculated the effect of the worst-case (wind conditions, RaLa source size) fallout on the Guaje reservoir (a partial source of Los Alamos water at that time) to be 0.1 uCi/L or 1 mR/day for continuous intake.	RaLa Shot	2	all
12/22/1949	RaLa shot # 142 took place at 1632 hours. The shot involved 1132 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SW. The wind speed was 3-5 mph. A “mild degree of contamination” was recorded in some parts of TA-1. No health hazard occurred; however, background activity may have been elevated enough to affect some TA-1 laboratory counting procedures.	RaLa Shot	2	all

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
1/13/1950	RaLa shot # 143 took place at 1248 hours. The shot involved 2065 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, SE. The wind speed was 25 mph.	RaLa Shot	2	all
1/17/1950	RaLa shot # 144 took place on 1/17/1950 at 1347 hours. The shot involved 1715 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the north and then east. The wind speed was 4-7 mph.	RaLa Shot	2	all
1/24/1950	RaLa shot # 145 took place on at 1138 hours. The shot involved 1737 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, NE. The wind speed was 25-30 mph. The cloud from the shot remained in Bayo Canyon.	RaLa Shot	2	all
1/31/1950	RaLa shot # 146 took place on 1/31/1950 at 1417 hours. The shot involved 981 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, NE. The wind speed was 9-17 mph.	RaLa Shot	2	all
3/24/1950	RaLa shot # 147 took place on 3/24/1950 at 1323 hours. The shot involved 1665 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E. The wind speed was 28-42 mph. A B-17 flight took place.	RaLa Shot	2	all
3/29/1950	RaLa shot # 148 took place at 1416 hours. The shot involved 1743 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W, WNW, and NNE. The wind speed was 2-8 mph. The maximum radiation measured at distance was 0.2 mR/h at 3 miles. "... a slight amount of contamination from fall-out was observed throughout the town site and Tech Area [TA-1]" following shot #148. It was obvious that weather conditions would not be ideal at shot time, but there was reluctance to cancel the shot for the day since weather predictions for the remainder of the week were no better. H Division authorized continuation of the operation. "The vast majority of it [the cloud] apparently moved out to the northwest toward the upper portions of Guaje Canyon. A small portion of the cloud ... took a southerly course and left detectable contamination in parts of the Los Alamos housing area (particularly in the Denver steel area), [which was the housing area closest to Bayo Canyon] and also in the Tech Area. The average levels of activity found were in the vicinity of 0.2 mr/h [Beta + gamma]... .There certainly is no reason to feel that the situation produced any health hazard whatsoever."	RaLa Shot	2	all
4/6/1950	RaLa shot # 149 took place at 1330 hours. The shot involved 1306 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NNW, NNE. The wind speed was 18-37 mph. A B-17 flight took place.	RaLa Shot	2	all
4/20/1950	RaLa shot # 150 took place at 1431 hours. The shot involved 3334 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NW. The wind speed was 4-12 mph.	RaLa Shot	2	all
4/26/1950	Rala shot # 151 took place on 4/26/1950 at 1400 hours. The shot involved 2496 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, SE. The wind speed was 5-30 mph. The Point Myrtle weather observer was directly under the cloud as it passed over but "he experienced no contamination."	RaLa Shot	2	all
5/12/1950	Rala shot # 152 took place on 5/12/1950 at 1359 hours. The shot involved 1355 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the S, SW. The wind speed was 10-15 mph.	RaLa Shot	2	all
5/24/1950	Rala shot # 153 took place on 5/24/1950 at 1152 hours. The shot involved 391 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 6-15 mph.	RaLa Shot	2	all
5/29/1950	On May 29, 1950 the contaminated waste disposal pit caught fire.	Fire	3483	7
6/27/1950	On June 27, 1950 -250 g of UO_3 were spilled during the transfer from a cabinet to the hood.	Contam. Event	3483	8
7/13/1950	Rala shot # 154 took place on 7/13/1950 at 1410 DST hours. The shot involved 1000 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE and N. The wind speed was 8-26 mph. The cloud motion observer's report stated "The cloud track given herein applies to only a small segment of the cloud. The bulk of the cloud seemed to dissipate without ever rising above the canyon walls."	RaLa Shot	2	all
8/18/1950	On August 18, 1950 a tank containing contaminated ammonium nitrate was found leaking. The floor and area was decontaminated.	Liquid Release	3483	8
10/3/1950	On October 3, 1950 a container of PuO_2 was opened and contaminated Room 513 of CMR 12.	User Error	3483	13
2/1/1951	On February 1, 1951 at Pajarito Site an experiment went critical during a remote control operation.	Criticality	1571	5

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
2/1/1951	On February 1, 1951 there was a criticality incident involving 2 cylinders of U-235. The cylinders weighted 24.4 kg and 38.5 kg of 93% U-235. The 2 cylinders were in a water reflected system. There was slight oxidation of the uranium. 10^{17} total fissions were involved.	Criticality	6206	all
9/13/1951	On September 13, 1951 in Room 201 of DP West a drybox caught fire contaminating the room.	Fire	3486	7
9/29/1951	On September 29, 1951 a bottle containing 10 grams of enriched U-235 was dropped in Room 307 spilling the contents on the floor.	Contam. Event	3486	9
10/6/1951	An accident occurred on October 6, 1951 and high levels of contamination were spread in Building 52 of DP East. Everyone leaving was monitored and two cars were found to be contaminated and they were cleaned before the employees left for home.	Air Release	3486	9
10/23/1951	On October 23, 1951 a beaker containing 8 hydroxy quinoline and plutonium exploded releasing contamination into Room D-304. The filter queen located in D-304 was changed immediately and very high levels of contamination were found. The amount of Pu present in the solution was not over 1-2 milligrams.	Explosion	3486	9
3/26/1952	Rala shot # 155 took place on 3/26/1952 at 1652 hours. The shot involved 270 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 20 mph. The maximum radiation measured at distance was 0.15 mR/h at 1.5 miles. Radiation monitoring started from Point Weather westward and included the northern part of the Los Alamos housing area; 0.04 mR/h was recorded 0.1 miles from Point Weather. No activity above background was detected elsewhere on return to TA-1. A second monitor started from the Main Hill Road intersection with State Road 4 and found no activity except "0.15 mr/h in the vicinity of the first large bend in the road east of the main guard gate." No activity was detected in TA-1.	RaLa Shot	2	all
4/18/1952	On April 18, 1952 there was a criticality incident involving 92.4 kg U metal 93% ^{235}U due to computation error $1.5x10^{16}$ total fissions were involved.	Criticality	6206	all
6/16/1952	On June 16, 1952 plutonium metal ignited in an open port drybox in D-138 of D Building. The fire was quickly quenched with water.	Fire	3495	9
8/11/1952	Rala shot # 156 took place on 8/11/1952 at 1755 hours. The shot involved 2400 Ci of RaLa with an explosive charge of 101 to 200 lbs. Monitoring began from Point Weather, where activity of 0.05 mR/h was recorded. At the picnic grounds (on North Mesa), background activity was recorded. At the Sportsman's Club and 35th and Diamond Drive, less than 0.1 mR/ h was recorded. Throughout North Community, activity was less than 0.05 mR/h. The survey sheet noted "... before shot background was 0.15, after shot 0.1 mr."	RaLa Shot	2	all
8/21/1952	Rala shot # 157 took place on 8/21/1952 at 1151 hours. The shot involved 2900 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. High-volume air samplers located at Station 20 (on Puye Road), White Rock, Well #3 (just east of Guaje pumice mine), and Totavi gave the following results: 239, 689, 460, and 931 cpm, respectively. Five-stage cascade impactor data were as follows: at White Rock, all five stages—0 cpm; at Well #3, 4th stage—31 cpm, 5th stage (Whatman #41 paper)—4 cpm; Totavi, 5th stage (molecular filter)—16 cpm.	RaLa Shot	2	all
8/29/1952	Rala shot # 158 took place on 8/29/1952 at 1259 hours. The shot involved 800 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E, NE. Air samplers run in Espanola and on Puye Road showed activity in the 30- to 100-nCi range. "Good coverage was obtained on the last Bayo shot [#158] and evaluation of these data has been completed showing no hazard in any inhabited areas."	RaLa Shot	2	all
12/9/1952	On December 9, 1952 in S-104 uranium in a furnace caught fire and was contained in the furnace. Clean-up of S-104 was conducted on December 11 and 12.	Fire	3495	11
1/8/1953	On January 8, 1953 a mock fission polonium beryllium source ruptured releasing as much as 2 Ci of Po. Significant amounts of polonium contamination was found in nearby homes.	Air Release	124	1
1/8/1953	On January 8, 1953 Po contamination was discovered at Pajarito Site Room 119 of Building 30. Employees of W-2 were exposed over a period of at least a week and several employee homes were contaminated. By January 13, 1953 all of W-2 and W-5 and SD houses were decontaminated.	Contam. Event	3492	1
4/3/1953	On April 3, 1953 the city dump was possibly contaminated with 125 lbs of tuballoy. 26 lbs were recovered, and the remainder was incinerated. The top layer of ashes was removed and three truck loads of dirt were placed over the contamination site.	User Error	191	53

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
6/10/1953	Rala shot # 159 took place on 6/10/1953 The shot was not fired, the explosive burned. Fallout trays on the main hill road and one high-volume air sampler in Guaje Canyon showed measurable activity. The monthly progress report of H-1 (the Health Physics Group) stated, "Although the east project access road [main hill road] was contaminated, the levels were low enough that they did not constitute a health hazard."	RaLa Shot	2	all
6/26/1953	On June 26, 1953 there was a small fire in a flask containing uranium hydride in D-151.	Fire	3491	4
6/29/1953	On June 29, 1953 an employee spilled approximately 40 μg of plutonium nitrate in Z Building on the floor. The area was decontaminated the following day.	Contam. Event	3491	5
8/10/1953	On August 10, 1953 a dissolver exploded releasing U-235 over the entire room.	Explosion	3491	9
8/14/1953	Rala shot # 160 took place on 8/14/1953 at 1402 hours. The shot involved 600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 10 mph.	RaLa Shot	2	all
9/10/1953	Rala shot # 161 took place on 9/10/1953 at ~1400 hours. The shot involved 250 Ci of RaLa with an explosive charge of 20 to 100 lbs.	RaLa Shot	2	all
10/9/1953	Rala shot # 162 took place on 10/9/1953 at ~1300 hours. The shot involved 215 Ci of RaLa with an explosive charge of 20 to 100 lbs.	RaLa Shot	2	all
11/12/1953	On November 12, 1953 there was an undetermined explosion in Room 501 that contaminated the room.	Explosion	3491	12
12/5/1953	On December 5, 1953 a glass furnace in a vacuum hood exploded releasing 40g of uranium.	Explosion	3491	13
1/28/1954	On January 28, 1954 a fire occurred at the contamination dump.	Fire	1184	233
2/1/1954	There have been 8 accidental prompt-critical excursions at Pajarito Site to date. The dates of the accidents are February 1951; April 1952, February 1954; July 1956; February 1957; June 1960; December 1962; May 1967. The only notable damage that occurred was in the February 1954 event. During that even there was a slight warping of the U(93) pieces, but no measurable fission-products were released.	Criticality	3167	18
2/1/1954	There was no measurable fission-product release during the worst accidental excursion at Pajarito, the second Lady Godiva accident.	Criticality	3168	1
2/3/1954	On February 3, 1954 there was a criticality incident involving 53 kg U metal 93% ^{235}U due to incorrect operation at the Lady Godiva reactor. There was a slight warping of the pieces. 5.6 x 10^{16} total fissions were involved.	Criticality	6206	all
2/8/1954	On February 8, 1954 in CMR- 4 tritium was released when a U-tube cracked under a hood.	Air Release	3493	2
2/12/1954	Rala shot # 163 took place on 2/12/1954 at 1620 hours. The shot involved 2730 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. Two air-sampling count data sheets provided the following information: one for Puye [Road], background activity; one for Espanola, 44 net cpm; no conversion to disintegrations per minute are given.	RaLa Shot	2	all
3/8/1954	Rala shot # 164 took place on 3/8/1954 at 1615 hours. The shot involved 2000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E.	RaLa Shot	2	all
3/19/1954	Rala shot # 165 took place on 3/19/1954 at 1130 hours. The shot involved 150 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
3/29/1954	On March 29, 1954 an 800-pound pig slipped and dropped off the tailgate of a pickup dumping a white powder on the truck and the dock. The area became contaminated with Sr-90 and was decontaminated. No one was allowed to wear contaminated clothing home.	User Error	3493	13
4/14/1954	Rala shot # 166 took place on 4/14/1954 at 1345 hours. The shot involved 190 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. No radiation was detected. Fallout was monitored starting at the main gate. Otowi ruins. White Rock, Mora's Castle (also known as the Duchess' Castle), Otowi Bridge, and 5 miles up Espanola highway (State Road 5) were surveyed from the main hill road. No readings above background were obtained.	RaLa Shot	2	all
4/19/1954	On April 19, 1954 a mixture containing 5 milligrams of americium exploded.	Explosion	3493	14
7/2/1954	Glass tube holding plutonium covered wire broke releasing Pu at Y Building on July 2, 1954.	Equipment Malfunction	2364	3

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/31/1954	RaLa shot # 167 took place at 1605 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 101 to 200 lbs. The maximum radiation measured at distance was 1.5 mR/h at 2.25 miles. The cloud started to the NE with very little velocity; the wind shifted shortly after the shot took place and spread fallout to the SE and S. A rain shower occurred in Bayo Canyon 35 minutes after the shot. Activity was detected between SR 4 and the Sandia Canyon guard station, one-half mile east of SR 4. Measurements in White Rock showed background activity. The next evening, 1 mR/h was measured at Otowi ruins. A hand-drawn fallout map was made, from which D. Meyer deduces, "Fallout area was approximately 4 square miles... average reading was 0.5 mr/hr with shield open at waist level. This equals to about 1 mr/hr at contact shield open or 0.15 mr/hr shield closed at 6" from ground."	RaLa Shot	2	all
8/5/1954	RaLa shot # 168 took place at 1830 hours. The shot involved 1500 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 0 mph. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles; 0.15 mR/h at 12 miles. The team made background readings in Rendija Canyon to the north and northeast several hours before the shot, finding elevated background activity from the previous shot (#167). After the shot, a counterclockwise survey began, reaching Totavi at 1845. The team returned up Guaje Canyon, encountering new fallout measuring 0.4 mR/h at the pumice mine (background in the morning was 0.04 mR/h) but found no further increase over the earlier background activity as far as the junction of Guaje and Rendija canyons. The team returned down Guaje Canyon and proceeded toward Espanola, encountering activity 4.5 miles south of Espanola with a maximum of 0.2 mR/h at the Puye Road turnoff. Activity was 0.15 mR/h at Santa Clara Pueblo and 0.1 to 0.15 mR/h in Espanola. The team returned to Puye Road the next morning and found slightly lower readings than the day before.	RaLa Shot	2	all
9/9/1954	RaLa shot # 169 took place at 1518 hours. The shot involved 265 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the S. The wind speed was 1 mph. The maximum radiation measured at distance 0.1 mR/h at 1 mile; 0.45 mR/hr at 2 miles 0.3 mR/hr at 2.5 miles; 0.18 mR/hr at 4 miles. The survey team passed the Los Alamos airstrip at 1538, where fallout was encountered; a maximum of 1.1 mR/h was recorded 1.4 miles east of the airport. Team members completed the survey including west up Guaje Canyon; all readings were background, which varied between 0.03 and 0.05 mR/h. More readings were taken the next day on other roads further south; a fallout map was prepared showing a relatively narrow fall-out pattern to the south-southwest over laboratory property, crossing Sandia Canyon, 0.45 mr/hr, and other east-west roads in the laboratory area.	RaLa Shot	2	all
9/16/1954	RaLa shot # 170 took place at 1458 hours. The shot involved 300 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NW. No radiation was detected. The team started a clockwise survey from TA-1 before 1500 and continued on to Espanola and Riverside (east side of Espanola). No fallout above background was detected. A map was made.	RaLa Shot	2	all
10/21/1954	An electrode broke within a flask causing tritium to be released into the hood in Room 220 of HRL Building on October 21, 1954.	Equipment Malfunction	2368	3
10/24/1954	U-235 material ignited spontaneously in the sigma vault on October 24, 1954.	Fire	2368	3
11/4/1954	RaLa shot # 171 took place at 1335 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 7 mph. The maximum radiation measured at distance was 0.3 mR/h at 1.5 miles. The team started a clockwise perimeter survey from TA-1 at 1600; background activity was 0.03 mR/h. All readings were background to State Road 4. The team returned up Guaje/Rendija Canyons and measured 0.3 mR/h for about 0.5 miles beginning 1.5 miles east of the Sportsman's Club. Apparently the activity was missed or had not yet arrived on the first pass.	RaLa Shot	2	all
11/16/1954	RaLa shot # 172 took place at 1500 hours. The shot involved 2440 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.3 mR/h 3.5 miles; 0.2 mR/h at 5 miles. The team began a clockwise perimeter survey at 1538 and encountered fallout in Guaje Canyon about 1.1 mile west of State Road 4 with a maximum of 0.2 mR/h at 1 mile west of State Roads 4. The team checked Totavi, background, and then started north on the Espanola Road (State Road 5). Very low readings (0.04 to 0.075 mR/hr) were found in the first 1.9 miles north of State Road 4 and 5 junction. The team returned west up Guaje Canyon; the measured maximum of 0.3 mR/h was again found 1 mile up canyon, essentially the same as before. Background seemed quite variable on this survey.	RaLa Shot	2	all

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
12/2/1954	RaLa shot # 173 took place at 1645 hours. The shot involved 1585 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNW. The maximum radiation measured at distance was 1 mR/h at 1.5 miles. Team members began a clockwise survey from TA-1 before 1730; background was 0.04 to 0.05 mR/h. They encountered fallout at the Sportsman's Club, which continued for 2.5 miles; the maximum reading of 1.0 mR/h was recorded 0.5 miles west of the Rendija Canyon gate.	RaLa Shot	2	all
12/7/1954	On December 7, 1954 Room 5006 of CMR Building was found to be highly contaminated. The exhaust fan for this room is not filtered, contamination was probably released into the environment.	Air Release	3493	21
12/9/1954	RaLa shot # 174 took place on 12/9/1954 at 1604 hours. The shot involved 500 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
12/30/1954	RaLa shot # 175 took place on 12/30/1954 at 1445 hours. The shot involved 320 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. No radiation was detected. The team surveyed Rendija and Guaje canyons. No readings above background were found, though spurious readings were encountered between the Sportsman's Club and the Rendija Canyon gate. These readings were explained as residual from previous shots. Although we have no fallout data on the previous shot, it seems unlikely that this explanation is valid because of the decay time.	RaLa Shot	2	all
1/1/1955	On one occasion during the year it was suspected that the city water line was contaminated due to corrosion. Tests did not detect contamination, but the repairs were made.	Liquid Release	3053	53
1/6/1955	RaLa shot # 176 took place on 1/6/1955 at 1415 hours. The shot involved 134 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles. A clockwise perimeter survey monitored Rendija and Guaje canyons as far as the well-drilling site below the Guaje pumice mine. Readings were 2 times background (0.07 mR/h) from the Rendija Canyon gate to 0.6 miles east of the gate. All other readings were background.	RaLa Shot	2	all
1/12/1955	RaLa shot # 177 took place on 1/12/1955 at 1415 hours. The shot involved 180 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The maximum radiation measured at distance (mR/h) was 0.12 mR/h at 1.3 miles. Two surveys were made in Rendija and Guaje canyons to about I mile past the pumice mine. Twice background, 0.07 mR/h, was measured from the Rendija Canyon gate about 0.6 miles east. All other readings were background.	RaLa Shot	2	all
1/13/1955	On January 13, 1955 a ampule of americium curium mixture exploded spreading contamination on two workers. The workers rinsed off in a sink and drove to the hospital. The route to the hospital and the vehicle was decontaminated.	Explosion	3489	4
3/9/1955	Uranium was released into the hood of Room 121 at TA-46 on March 9, 1954.	Air Release	2383	2
3/17/1955	RaLa shot # 178 took place on 3/17/1955 at 1255 hours. The shot involved 3160 Ci of RaLa with an explosive charge of 201 to 350 lbs. The cloud tracked toward the NE. No radiation was detected. A northern perimeter survey was done in Rendija and Guaje canyons, down and back. All readings showed background activity.	RaLa Shot	2	all
3/23/1955	RaLa shot # 179 took place at 1315 hours. The shot involved 2260 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 8-15 mph. The maximum radiation measured at distance was 0.3 mR/h at 3 miles. A clockwise perimeter survey starting about 1400 found only background activity in Rendija and Guaje canyons. The team encountered fallout just east of Totavi (0.1 mR/h), which increased through Totavi and reached 0.3 mR/h at 0.2 miles west of Totavi and continued for 0.3 miles. The team retraced its route to check further east of Totavi to Otowi Bridge; readings showed background activity. Activity at the White Rock Y (intersection of main hill road and State Road 4) measured 0.1 mR/h; measurements taken towards and in White Rock were all background. A reading of 1 mR/h was recorded at Otowi ruins by another team. A rough map was drawn.	RaLa Shot	2	all

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
3/30/1955	RaLa shot # 180 took place at 1315 hours. The shot involved 2642 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 6-10 mph. The maximum radiation measured at distance was 0.6 mR/h at 2 miles. The general background activity in the Los Alamos area was elevated because of fallout from the Nevada Test Site (NTS). Background activity of 0.5 mR/h was measured in TA-1, 0.1 to 0.2 mR/h on State Road 4 to Totavi, and 0.1 to 0.15 mR/h on North and Tank (Barranca) mesas. The Guaje-Rendija survey passed the Sportsman's Club at 1415, where the background due to NTS fallout was 0.3 mR/h. The team found readings in excess of this background and attributed these readings to activity from this shot for about 1 mile west of the Guaje pumice mine to the mine.	RaLa Shot	2	all
4/7/1955	RaLa shot # 181 took place at 1522 hours. The shot involved 2080 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 5 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.2 miles. The team stalled the Rendija and Guaje canyons survey from TA-1 at 1600; encountering activity 1.9 miles past the Sportsman's Club. This activity continued for about 1 mile, with a maximum of 0.07 mR/h measured 0.1 miles east of the Rendija Canyon gate to 0.5 miles past the Guaje pumice mine. Here the team turned around and retraced its path. At 1654, the reading at the Sportsman's Club had increased to 0.075 mR/h. It was noted that “residual readings of 0.04 to 0.06 mr/hr from NTS test fallout a week ago prevailed throughout the survey area.”	RaLa Shot	2	all
4/22/1955	RaLa shot # 182 took place at 1810 hours. The shot involved 700 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.4 mR/h at 1.5 miles. The team began to survey Rendija and Guaje canyons at 1845; background activity was 0.03 mR/h. Activity was encountered 2.3 miles past the Sportsman's Club and continued for about 1 mile, with a maximum of 0.4 mR/h 2.3 miles past the Sportsman's Club.	RaLa Shot	2	all
4/28/1955	RaLa shot # 183 took place at 1515 hours. The shot involved 3200 Ci of RaLa with an explosive charge of 101 to 200 lbs.	RaLa Shot	2	all
5/5/1955	RaLa shot # 184 took place at 1540 hours. The shot involved 2560 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.2 mR/h at 2 miles. A team surveying Rendija and Guaje canyons passed the Sportsman's Club at 1625; background was 0.02 to 0.04 mR/h. The team encountered fallout 2 miles further at Rendija Canyon gate; fallout continued to 0.7 miles past the Guaje pumice mine. A maximum reading of 0.2 mR/h was measured 0.4 miles east of the junction of Rendija and Guaje canyons. All other readings were background.	RaLa Shot	2	all
5/12/1955	On May 12, 1955 a small furnace erupted releasing an unknown quantity estimated at less than one kilogram of uranium in Room 102 of Sigma Building.	Explosion	2374	6
5/12/1955	There was a tuballoy fire in Sigma Building, Room 103 on May 12, 1955.	Fire	3489	10
5/12/1955	RaLa shot # 185 took place at 1625 hours. The shot involved 2100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph. No radiation was detected. Rendija and Guaje canyons were surveyed. All readings showed background activity.	RaLa Shot	2	all
5/20/1955	RaLa shot # 186 took place at 1845 hours. The shot involved 1470 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.5 mR/h at 1.5 miles. Rendija and Guaje canyons were surveyed. Activity at the Rendija Canyon gate was 0.18 mR/h. At 0.2 miles east of the Rendija Canyon gate, the reading was 0.5 mR/h. All other readings were 0.08 to 0.1 mR/h.	RaLa Shot	2	all
5/26/1955	RaLa shot # 187 took place at 1154 hours. The shot involved 520 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 4-7 mph. The maximum radiation measured at distance was 1 mR/hr at 1.2 miles. Rendija and Guaje canyons were surveyed. All readings were background, which was noted as “elevated from previous shot.” A reading of 1 mR/h was recorded at Otowi ruins.	RaLa Shot	2	all
6/2/1955	RaLa shot # 188 took place at 1345 hours. The shot involved 490 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph. The maximum radiation measured at distance was 0.16 mR/h at 1.5 miles. Rendija and Guaje canyons were surveyed. The path of fallout extended 0.3 miles west of the Rendija Canyon gate to 0.8 miles east. The highest reading was 0.16 mR/h. D. Meyer's handwritten note says, “no fallout found”; we assume he interpreted the fallout as resulting from previous shot(s).	RaLa Shot	2	all

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/21/1955	On July 21, 1955 some normal uranium caught fire in Room 1131.	Fire	1184	466
8/3/1955	On August 3, 1955 a mock fission polonium source containing 25.2 curies of Po exploded in the basement of the Physics Building. Contamination was spread through out the Physics Building.	Explosion	2377	3
8/19/1955	On August 19, 1955 an employee dropped a test tube containing one gram of normal uranium in Wing 2 of CMR Building.	User Error	3489	14
9/6/1955	On September 6, 1955 a radiation contamination incident occurred in Room 1 of ML Building.	Contam. Event	3489	14
9/16/1955	RaLa shot # 189 took place at 1455 hours. The shot involved 2600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.2 mR/h at 2 miles. The team began a clockwise perimeter survey from Point Weather at 1500; background was 0.03 mR/h. The highest reading of 0.2 mR/h was measured at Point Weather (which must have been direct radiation from the firing pad, reading 65 R/h at a meter above the firing pad after the shot). Fallout was encountered in Guaje Canyon at the pumice mine, continuing for 1.2 miles with a maximum of 0.2 mR/h recorded 0.3 miles east of the pumice mine.	RaLa Shot	2	all
9/28/1955	RaLa shot # 190 took place at 1631 hours. The shot involved 2600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph.	RaLa Shot	2	all
10/7/1955	RaLa shot # 191 took place at 1515 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was light. The maximum radiation measured at distance was 2 mR/h at 1.5 miles. The team began a clockwise survey from TA-1 at 1555; background was 0.03 mR/h. Fallout was encountered 1.4 miles east of the Sportsman's Club, which continued about 0.6 miles down Rendija Canyon. The team continued west up Guaje Canyon, encountering fallout 0.2 miles west up canyon; this fallout continued for 1.1 miles with a peak of 1 mR/h recorded 0.8 miles west up canyon. The team completed the survey down Guaje Canyon and returned through Totavi. All activity was background.	RaLa Shot	2	all
10/19/1955	RaLa shot # 192 took place at 1720 hours. The shot involved 2000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.5 mR/h 6 miles. The team began a counterclockwise survey past the main gate at 1800; background was 0.01 to 0.03 mR/h. The team encountered activity 0.4 miles north on Espanola Road (State Road 5), which continued for about 3 miles. A maximum reading of 0.5 mR/h was measured. The team surveyed around the gravel pits near the Rio Grande, south of Pajarito Village; a maximum of 2 mR/h probably was influenced by several particles, judging from the lower readings on State Road 5. One particle read 1.4 mR/h beta plus gamma at “contact,” and another read 11 mR/h gamma at 6 inches, using a Cutie Pie ion-chamber survey instrument. Later, photomicrographs, autoradiographs, and activity determinations of two particles were made; each particle measured over 300 microns in the longest dimension.	RaLa Shot	2	all
10/26/1955	RaLa shot # 193 took place at 1630 hours. The shot involved 3987 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 1 mR/h at 3 miles; 0.1 mR/h at 10 miles. The team began a counterclockwise perimeter survey from TA-1 at 1725; background was 0.03 mR/h. All readings showed background activity until 5.4 miles past Totavi on Espanola Road (State Road 5), where fallout was encountered that continued to Santa Clara Pueblo; a maximum of 0.15 mR/h was found at Puye Road. The team returned up Guaje Canyon, encountering fallout 1.8 miles west up canyon, which continued for about 1 mile. The maximum reading of 1.0 mR/h was recorded 1 mile east of the Guaje pumice mine. The remainder of the perimeter survey readings showed background activity.	RaLa Shot	2	all

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
11/3/1955	RaLa shot # 194 took place at 1605 hours. The shot involved 3500 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was 7 mph. The maximum radiation measured at distance was 1.6 mR/h at 1.5 miles; 3.0 mR/h at 2 miles; 0.2 mR/h at 5 miles. The team began a clockwise perimeter survey from TA-1 at 1645; background activity was 0.04 mR/h. Fallout was encountered 2.1 miles past the Sportsman's Club and continued for about 1 mile. A maximum reading of 1.6 mR/h was recorded 0.3 miles further on. The team went west up Guaje Canyon, encountering fallout 0.3 miles up canyon. The fallout continued for about 1 mile, with a maximum of 3.0 mR/h recorded between 0.6 to 0.7 miles west up canyon. The remainder of the perimeter survey was completed down Guaje Canyon, through Totavi, and back to TA-1. All readings showed background activity. The following morning Puye Road was surveyed, with readings fluctuating between 0.1 and 0.2 mR/h from the Espanola Road (State Road 5) to the Puye Ruins.	RaLa Shot	2	all
11/17/1955	RaLa shot # 195 took place at 1354 hours. The shot involved 1600 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 8-10 mph. The maximum radiation measured at distance was 0.65 mR/h at 1.5 miles; 0.3 mR/h at 2 miles. The team began a clockwise perimeter survey from TA-1 at 1430; background was 0.03 mR/h. Fallout was encountered 0.7 miles past the Sportsman's Club and continued for 1.4 miles, with a maximum of 0.65 mR/h recorded 1.7 miles past the Sportsman's Club. The team surveyed west up Guaje Canyon; a maximum of 0.3 mR/h was recorded 2 miles up the canyon.	RaLa Shot	2	all
11/29/1955	RaLa shot # 196 took place at 1535 hours. The shot involved 780 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 5-7 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles; 0.4 mR/h at 2 miles. The team began a clockwise perimeter survey from TA-1 at 1625; background was 0.03 mR/h. Fallout was encountered at the Rendija Canyon gate and continued for 0.8 miles, with a maximum of 0.7 mR/h measured 0.4 miles beyond. The fallout pattern also crossed upper Guaje Canyon with a maximum of 0.4 mR/h about a mile west up canyon. Above-background readings were recorded for about 3 miles to Guaje Canyon gate, where the team completed the survey through lower Rendija and Guaje canyons to Totavi. Only background activity was found.	RaLa Shot	2	all
1/27/1956	RaLa shot # 197 took place at 1443 hours. The shot involved 1300 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the E. No radiation was detected. The team began a special survey from TA-1 at 1500; background activity was 0.05 mR/h. Since the cloud remained in Bayo Canyon, the team surveyed only in the eastern part of the canyon to the Otowi ruins, recording a maximum of 0.4 mR/h at 0.3 miles west up Bayo Canyon from State Road 4. A rough sketch was made.	RaLa Shot	2	all
2/1/1956	In 1956 approximately 1 Ci of Sr was released into Mortandad canyon when a line broke on a full tank of waste.	Liquid Release	1733	20
2/11/1956	During the week of February 11, 1956 a pipe carrying water near Ten Site developed a leak releasing 35,000 gallons of contaminated water into Mortandad canyon.	Liquid Release	2382	2
2/21/1956	RaLa shot # 198 took place at 1805 hours. The shot involved 2100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.7 mR/h at 3 miles. The team began a clockwise perimeter survey from TA-1 at 1830; background activity was 0.05 mR/h. The picnic grounds and stables (on North Mesa), and Tank Mesa (Barranca Mesa) were surveyed; background activity was recorded. Fallout was encountered 1.1 miles past the Guaje pumice mine and continued for 1.3 miles with a maximum of 0.7 mR/h recorded 0.6 miles past the mine.	RaLa Shot	2	all
3/1/1956	RaLa shot # 199 took place at 1540 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 7 mph. The maximum radiation measured at distance was 1.0 mR/h at 2 miles. The team began a counterclockwise perimeter survey from TA-1 at 1630; the background activity was 0.03 to 0.05 mR/h. Fallout was encountered in Guaje Canyon just east of the pumice mine and continued for almost 3 miles. A maximum of 1.0 mR/h was recorded about 0.2 miles past the Rendija/Guaje Y. The team returned west up Rendija Canyon, measuring 0.1 to 0.2 mR/h for about 0.8 miles. Tank Mesa (Barranca Mesa) and North Mesa were surveyed; only background activity was noted.	RaLa Shot	2	all
3/9/1956	On March 9, 1956 a spill of uranium flowed into the bottom of the furnace in Room 21 of the Sigma Building.	Contam. Event	2383	2

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
3/9/1956	RaLa shot # 200 took place at 1730 hours. The shot involved 435 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The wind speed was 8-12 mph.	RaLa Shot	2	all
3/14/1956	RaLa shot # 201 took place at 1345 hours. The shot involved 560 Ci of RaLa with an explosive charge of 101 to 200 lbs. No radiation was detected. The team began a counterclockwise perimeter survey from TA-1 at 1408; the background activity was 0.05 mR/h. All measurements were background.	RaLa Shot	2	all
3/22/1956	RaLa shot # 202 took place at 1330 hours. The shot involved 389 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The maximum radiation measured at distance was 0.15 mR/h at 2.2 miles. The survey team left TA-1 at 1420; background radiation was 0.03 mR/h. A reading of 0.04 mR/h was recorded at the picnic grounds (on North Mesa), 0.15 mR/h at "overlook of Bayo" [tip of Otowi Mesa, called also "North Ridge"—probably direct radiation from the firing pad, which was reading 40 R/h waist high above the pad shortly after the shot]. Readings on the "mesa north of previous measurement (0.15 mr/hr)," (Deer Trap Mesa, northeastern-most Barranca Mesa) were background. At 2.7 miles east of the Sportsman's Club, fallout of 0.12 mR/h was encountered. At 2.9 miles, fallout was 0.15 mR/h, and at Booster #1 (near Guaje/Rendija Y) it was 0.08 mR/h. About 0.5 miles up Guaje Canyon, fallout was 0.13 mR/h.	RaLa Shot	2	all
4/7/1956	RaLa shot # 203 took place at 1730 hours. The shot involved 1520 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the ESE. The wind speed was 8 mph. The maximum radiation measured at distance was 1.0 mR/h at 4 miles. The team departed TA-1 at 1812; background activity was 0.03 mR/h. Background activity was measured until the team reached the "tip of Tank Mesa [Barranca Mesa]," where the reading was 0.3 mR/h (direct radiation from the firing pad may have affected this measurement). A clockwise perimeter survey was continued. Background activity was recorded until the Guaje Canyon road junction with State Road 4; at that point, the reading was 0.10 mR/h. Background activity was recorded further east to the junction of State Roads 4 and 5. Readings increased to 1.0 mR/h at Roy's Service Station (Totavi); continuing 0.6 miles west, only background activity was found to TA-1. The cloud did not rise above the Bayo Canyon walls and apparently followed the canyon to Totavi.	RaLa Shot	2	all
4/12/1956	RaLa shot # 204 took place at 1455 hours. The shot involved 3740 Ci of Rala with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 12 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles; 0.07 mR/h at 5.5 miles. The team began a clockwise survey from TA-1 at 1555; background activity was 0.03 mR/h. Down Rendija Canyon, 2 miles past the Sportsman's Club, the team encountered fallout measuring 0.05 mR/h, with a maximum of 0.7 mR/h recorded 2.5 miles beyond. Activity slowly decreased to background activity within half a mile. The team continued down Guaje Canyon to State Road 4 and north to Puye Road junction and then west, encountering 0.07 mR/h 6 to 6.4 miles west on Puye Road, essentially directly in line with the previous encounter in Guaje Canyon. The next morning the team monitored in Espanola, Riverside, and Fairview (areas east and north of Espanola); only background activity was detected.	RaLa Shot	2	all
4/20/1956	RaLa shot # 205 took place at 1436 hours. The shot involved 3200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was 8 mph. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles. The team began a clockwise survey from TA-1 at 1506; background activity was 0.03 mR/h. Team members encountered fallout about 0.7 miles past the Sportsman's Club. Activity was 0.09 mR/h, falling to 0.05 mR/h in the next 0.3 miles. Only background activity was found at Booster #1 (3 miles east past the Sportsman's Club) and for 2.3 miles west up Guaje Canyon. At 2.3 miles, fallout was encountered, which increased to a broad maximum of 0.4 mR/h for 0.4 miles, continued at this level for 0.4 miles, and then decreased to 0.15 mR/h at the Guaje Canyon gate.	RaLa Shot	2	all
4/26/1956	RaLa shot # 206 took place at 1140 hours. The shot involved 2195 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 5 mph. No radiation was detected. The survey team left TA-1 at 1223; background activity was 0.03 mR/h. The team made the complete perimeter survey and found no readings above background. The cloud was observed to start to the north and then spread east along the canyon rim.	RaLa Shot	2	all
5/10/1956	RaLa shot # 207 took place at 1145 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 20 to 100 lbs. No radiation was detected. The survey team left TA-1 at 1310; background activity was 0.03 mR/h. The perimeter survey was completed with no readings above background recorded.	RaLa Shot	2	all

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
5/21/1956	RaLa shot # 208 took place at 1300 hours. The shot involved 4,000 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NW. The maximum radiation measured at distance was 0.16 mR/h at 1.5 miles. The team began a clockwise perimeter survey from the Administration Building (TA-3, SM-43) at 1340 (note the new starting point); background activity was 0.03 mR/h. Fallout was encountered from 0.9 to 1.2 miles east of the Sportsman's Club, and the maximum activity was 0.15 mR/h beyond the Sportsman's Club. The team completed the survey route, finding only background activity. The cloud was observed to move to the south Bayo Canyon wall and then rise and move north.	RaLa Shot	2	all
5/25/1956	RaLa shot # 209 took place at 1155 hours. The shot involved 4195 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.8 mR/h at 1.5 miles; 1.2 mR/h at 2 miles. The survey team left Point Weather at 1200 (only 5 minutes after the shot) and immediately measured 13 mR/h (probably direct radiation from the cloud, not fallout). On the continuing clockwise perimeter survey, fallout (0.1 mR/h) was encountered 1.4 miles east of the Sportsman's Club and continued above background with peaks of 0.8 mR/h at the Barranca (Rendija) gate and 1.2 mR/h 0.4 miles west up Guaje Canyon. The remainder of the survey found no activity above background.	RaLa Shot	2	all
6/7/1956	RaLa shot # 210 took place at 1455 hours. The shot involved 2907 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles. The team left the Administration Building (SM-43) at 1416; background activity was 0.03 mR/h to Point Weather, where the reading was 0.07 mR/h (probably a direct reading from the firing pad). Fallout was encountered 0.6 miles past the Sportsman's Club, with a maximum of 0.7 mR/h recorded 1.8 miles east. It continued above background for another 0.6 miles. The team completed surveying the rest of the perimeter, encountering only background activity.	RaLa Shot	2	all
6/14/1956	RaLa shot # 211 took place at 1305 hours. The shot involved 1840 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the WSW. The wind speed was light (5) mph. No radiation was detected. The survey team left the Administration Building (SM-43) at 1315; background activity was 0.03 mR/h; activity at Point Weather was 0.07 mR/h. Only background activity was encountered on the perimeter survey. The section of State Road 4 road toward White Rock was also checked and background found.	RaLa Shot	2	all
7/3/1956	On July 3, 1956 there was a criticality incident involving 58 kg U in the form of 93% U-235 as 2- and 5-mil foils. Changes were made in the reflector and graphite moderator and criticality was reached too quickly. 3.2×10^{16} total fissions were involved.	Criticality	6206	all
10/5/1956	RaLa shot # 212 took place at 1428 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NW and N. The wind speed was 13 mph. The maximum radiation measured at distance was 1.3 mR/h at 1.5 miles; 1.3 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1555; background activity was 0.03 mR/h; activity at Point Weather was 0.5 mR/h. Fallout was encountered 1.3 miles east of the Sportsman's Club and continued for 3.1 miles, with a peak between 1.0 and 1.3 mR/h recorded 2.1 miles east of the Club. Fallout also crossed Guaje Canyon beginning 0.5 miles west up Guaje Canyon and continuing above background for 2.1 miles. A maximum reading of 1.3 mR/h was recorded 1.l miles west up canyon.	RaLa Shot	2	all
10/16/1956	RaLa shot # 213 took place at 1534 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The wind speed was 5 mph. The maximum radiation measured at distance was 0.8 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1605; background activity was 0.03 mR/h. Fallout was encountered 2.4 miles east of the Sportsman's Club (0.1 mR/h) and 0.8 miles west up Guaje Canyon (0.8 mR/h). During the remainder of the clockwise perimeter survey, only background activity was detected.	RaLa Shot	2	all
10/23/1956	On October 23, 1956; 100 mg of plutonium hexafluoride exploded in a drybox in Room 5122 of CMF 2. The material entered the exhaust system of the drybox and was vented into the filter tower for Wing 5. The filter tower filters were changed and monitored for contamination.	Explosion	4055	6

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
10/27/1956	RaLa shot # 214 took place at 1420 hours. The shot involved 300 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 10 mph. The maximum radiation measured at distance was 0.5 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1501; background activity was 0.04 mR/h. Fallout was encountered 1.3 miles east past the Sportsman's Club, with a peak of 0.5 mR/h occurring 0.5 miles further on. The peak reading was caused by a one-foot-square contaminated area measuring 6 mR/h at 6 inches (probably one or more particles).	RaLa Shot	2	all
11/1/1956	RaLa shot # 215 took place at 1023 hours. The shot involved 200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 9 mph. The maximum radiation measured at distance was 0.3 mR/h at 1.5 miles; 0.15 mR/h at 2.3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1100; background activity was 0.03 mR/h. Fallout was encountered 0.5 miles east of the Sportsman's Club, with a peak of 0.3 mR/h occurring 1.7 miles past the Sportsman's Club. Above-background readings continued to the Rendija/Guaje canyons junction and then increased west up Guaje Canyon, with a peak of 1.5 mR/h occurring 1.8 miles up the canyon and continuing above background for about 1 mile. The team completed the perimeter survey down Guaje Canyon to Highway 4 and returned to the Administration Building; only background activity was detected.	RaLa Shot	2	all
12/5/1956	RaLa shot # 216 took place at 1500 hours. The shot involved 800 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 17 mph. The maximum radiation measured at distance was 1.0 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1515; background activity was 0.03 mR/h. Fallout was encountered 1 mile past the Sportsman's Club and continued for 0.8 miles, with a peak of 1.0 mR/h occurring 1.4 miles past the Sportsman's Club. The perimeter survey was completed with positive readings recorded 1 mile east of the main gate. Peak activity of 0.4 mR/h occurred at the entrance to the East Gate Lab. No explanation was offered for these later readings, which are in the opposite direction from which the main cloud was detected. Operations at the East Gate Laboratory are suspected (see shots #238, 240, and 242).	RaLa Shot	2	all
12/20/1956	RaLa shot # 217 took place at 1450 hours. The shot involved 225 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the W and SW. The wind speed was 3 mph. The maximum radiation measured at distance was 1 mR/h at 0.6 miles; 0.3 mR/h at 1 mile; 0.5 mR/h at 2 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1510; background activity was 0.05 mR/h. A reading of 0.3 mR/h was recorded at the dump site near the Los Alamos Airport. The team completed the perimeter survey; all readings showed only background activity. A town site survey began at 1700; a peak of 0.15 mR/h was recorded at the eastern end of Manhattan Loop (eastern residential area). Activity up to 0.075 mR/h was recorded at the DP Road trailer court (south of the airport). At 0.1 miles west of Point Weather, activity from 1 mR/h to 0.5 mR/h was recorded to the ballpark (on North Mesa), where background activity was measured.	RaLa Shot	2	all
2/7/1957	On February 7, 1957 an explosion and fire occurred in the pure metal drybox in Room 406 of DP West. The only contamination found was on the outside of the air intake filters.	Explosion	4056	16
2/8/1957	On February 8, 1957 tinners disconnected the exhaust duct on the wooden drybox line in Room 500. Highly contaminated dust spread throughout the south part of the room.	Air Release	3490	11
2/12/1957	At 3 pm on February 12, 1957 the Godiva assembly located at Kiva 2 at Pajarito Site went supercritical. Filters in the heating system were found to be highly contaminated. The exhaust system was not running at the time of the incident.	Criticality	2817	1-2
2/12/1957	On February 12, 1957 there was a criticality incident involving 54 kg U metal 93% U-235 due to incorrect operation at the Lady Godiva reactor. There was warping oxidation near melting close to center. 1.2 x 10^{17} total fissions were involved.	Criticality	6206	all
3/7/1957	On March 7, 1957 a worker in Room 2125 Wing 2 of CMR Building was working with 20 grams of plutonium in a glovebox when they noticed that there was a leak in the glove.	Air Release	3490	19

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
3/16/1957	RaLa shot # 218 took place at 1245 hours. The shot involved 2140 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 15 mph.	RaLa Shot	2	all
3/27/1957	On March 27, 1957 an explosion occurred in the machine lathe drybox in Room 500. The operator of the lathe was highly contaminated. After showering no contamination was detected.	Explosion	3490	23
3/29/1957	RaLa shot # 219 took place at 1250 hours. The shot involved 3079 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the E. The wind speed was 6 mph. The maximum radiation measured at distance was 0.1 mR/h at 3 miles; 0.07 mR/h at 7 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1330; background activity was 0.03 mR/h. A reading of 0.1 mR/h was recorded at the stables (on North Mesa), but it was questioned on the survey sheet as not being reasonable, probably because the cloud was reported to have gone to the east. Fallout of 0.07 mR/h was encountered in Guaje Canyon 0.7 miles past the pumice mine, continuing for about 0.5 miles, with a peak of 0.1 mR/hr halfway between. Activity between 0.5 and 0.07 mR/h was recorded north on State Road 5, 3.2 miles from the junction.	RaLa Shot	2	all
4/17/1957	RaLa shot # 220 took place at 1630 hours. The shot involved 3249 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The wind speed was 12 mph. The maximum radiation measured at distance was 0.4 mR/h at 4.5 miles. The team left the Administration Building (SM-43) at 1650; background activity was 0.03 mR/h. During the counterclockwise perimeter survey, fallout (0.04 mR/h) was encountered at the junction of the Main Hill Road/ White Rock cutoff. It increased to a maximum of 0.4 mR/h at 0.3 miles before the junction of Guaje Canyon and State Road 4. At Otowi Bridge, activity was 0.08 mR/h; at the Espanola Highway (State Road 5) to Puye Road, it was 0.08 to 0.09 mR/h for 3 miles. At the entrance to Guaje Canyon, activity was 0.2 mR/h and persisted to the Guaje pumice mine, where the 0.08 mR/h reading was attributed to contamination on the vehicle since the reading continued at this level until the team returned to the Administration Building. Weather observations confirmed that the cloud did not rise above the canyon walls to reach the southwest winds.	RaLa Shot	2	all
5/9/1957	RaLa shot # 221 took place at 1600 hours. The shot involved 1000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 7 mph. No radiation was detected. The team began a clockwise survey from Administration Building (SM-43) at 1630; background activity was 0.04 mR/h. A clockwise perimeter survey was completed that included Puye Road; no measurable fallout was detected. Weather observations of the cloud support these findings. The cloud remained in Bayo Canyon.	RaLa Shot	2	all
6/5/1957	There was a fire in the back of a contaminated dump truck on June 5, 1957.	Fire	3490	23
6/13/1957	On June 13, 1957 there was a contamination incident in Room 513 of DP West. The contamination occurred during the cleaning out of a Lucite casting tunnel.	Contam. Event	3490	49
6/20/1957	RaLa shot # 222 took place at 1540 hours. The shot involved 1000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 12 mph. No radiation was detected. The team left the Administration Building (SM-43) at 1625; background was 0.03 mR/h. A counterclockwise survey included the Puye pumice mine; the survey team returned through Guaje Canyon. The recorded instrument readings fluctuated between 0.02 and 0.05 mR/h but were considered negative. Weather observations confirmed that the cloud remained in the canyon.	RaLa Shot	2	all
7/10/1957	RaLa shot # 223 took place at 1625 hours. The shot involved 2257 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The wind speed was 8 mph. The maximum radiation measured at distance was 0.6 mR/h at 1.5 miles. The team began a clockwise survey from Administration Building (SM-43) at 1640; background activity was 0.05 mR/h. Fallout was encountered 0.4 miles east past the Sportsman's Club, with a maximum of 0.6 mR/h recorded just beyond and falling to background 0.8 miles past the Sportsman's Club.	RaLa Shot	2	all
7/11/1957	On July 11, 1957 a leak was discovered in the buried acid waste tank outside Building #35 DP West. The contaminated ground was dug up and put into metal containers to be disposed of in the contamination dump.	Liquid Release	721	49

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/23/1957	RaLa shot # 224 took place at 1306 hours. The shot involved 1520 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 8 mph. The maximum radiation measured at distance was 0.6 mR/h at 1.5 miles; 1.0 mR/h at 2.2 miles; 0.08 mR/h at 4 miles. The team began a clockwise survey from Administration Building (SM-43) at 1335; background activity was 0.05 mR/h. Fallout was encountered 1.2 miles east past the Sportsman's Club, with a maximum of 0.6 mR/h recorded 1.4 miles past the Sportsman's Club. The same reading was recorded 2.0 miles past the Sportsman's Club. A reading of 1.0 mR/h was recorded 1.6 miles west up Guaje Canyon; 0.08 mR/h was recorded at the Puye pumice mine, although the same reading was recorded at the Administration Building, which does not seem reasonable. Contamination on the detector or the vehicle is suspected.	RaLa Shot	2	all
8/15/1957	On August 15, 1957 an explosion occurred in a glove box chain in Room 500. 18 rubber gloves were torn and three safety windows were cracked. Five men were contaminated, no skin contamination was detected after showering.	Explosion	4056	8
8/16/1957	On August 16, 1957 an explosion occurred in a glovebox chain in Room 500. Five men were contaminated with Pu.	Explosion	3490	53
8/30/1957	On August 30, 1957 large quantities of plutonium contamination were dispersed over the floor, hood and sink in three labs in J-11, contamination was also detected in the J-2 Building hallway.	Air Release	2413	4
9/27/1957	On September 27, 1957 rags contaminated with sodium and uranium caught fire in Room 133 at Ten Site. Fire was quickly extinguished with CO2.	Fire	2414	3
9/27/1957	RaLa shot # 225 took place at 1607 hours. The shot involved 1960 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.8 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1707; background activity was 0.05 mR/h. Fallout was encountered 1.4 miles east past the Sportsman's Club, with a maximum of 0.8 mR/h recorded 1.5 miles past the Sportsman's Club.	RaLa Shot	2	all
10/10/1957	RaLa shot # 226 took place at 1726 hours. The shot involved 1153 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 7 mph. The maximum radiation measured at distance (mR/h) was 0.3 mR/h at 2.2 miles. The team began a clockwise survey and reached the Sportsman's Club at 1814; background activity was 0.03 mR/h. Fallout was encountered 0.2 miles past the Rendija/Guaje junction, with a maximum of 0.3 mR/h recorded 0.4 miles down canyon. Activity continued above background until past the Guaje pumice mine. During the rest of the survey, only background activity was recorded.	RaLa Shot	2	all
11/12/1957	On November 12, 1957, a vial containing 14,000 c/m of plutonium was dropped at the stairs leading from the first floor of HRL Building.	User Error	2489	3
1/30/1958	RaLa shot # 227 took place at 1302 hours. The shot involved 1340 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the E. The wind speed was 13 mph. The maximum radiation measured at distance was 0.16 mR/h at 3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1343; background activity was 0.02 mR/h. Fallout was encountered at Well #1 and continued for 1.8 miles, with a maximum of 0.16 mR/h recorded 1.3 miles west up canyon from State Road 4.	RaLa Shot	2	all
2/19/1958	RaLa shot # 228 took place at 1545 hours. The shot involved 1850 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The wind speed was 5 mph. The maximum radiation measured at distance was 5 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1625; background activity was 0.02 mR/h. Fallout was encountered at the Sportsman's Club, with a maximum of 5 mR/h recorded one mile east past the Sportsman's Club. Above background readings continued to Booster #2 at the junction of Rendija and Guaje canyons.	RaLa Shot	2	all

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
3/7/1958	RaLa shot # 229 took place at 1655 hours. The shot involved 1800 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The maximum radiation measured at distance was 1.0 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1743; background activity was 0.03 mR/h. Fallout was encountered 1.9 miles east past the Sportsman's Club, with a maximum of 1.0 mR/h recorded 2.1 miles past the Sportsman's Club. Above-background activity was recorded to the junction of Rendija/ Guaje canyons.	RaLa Shot	2	all
4/3/1958	RaLa shot # 230 took place at 1505 hours. The shot involved 1100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NW, NE. The wind speed was 5 mph. No radiation was detected. The team began a clockwise survey from the Administration Building (SM-43) at 1535 for a clockwise perimeter survey. All readings showed background activity.	RaLa Shot	2	all
5/1/1958	RaLa shot # 231 took place at 1430 hours. The shot involved 1134 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNW. The wind speed was 10 mph.	RaLa Shot	2	all
6/3/1958	RaLa shot # 232 took place at 1450 hours. The shot involved 1316 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 12 mph. The maximum radiation measured at distance was 0.18 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1535; background activity was 0.05 mR/h. Fallout was encountered at the Rendija/Guaje junction, with a maximum of 0.18 mR/h recorded 0.7 miles down canyon. The remainder of the survey recorded background activity.	RaLa Shot	2	all
7/25/1958	On July 25, 1958 at TA-33, a leak occurred in Building 86 causing tritium to be released. The site was evacuated and road blocks were set up.	Air Release	2422	4
7/25/1958	Large quantities of tritium were released in the filling chamber of Room 9 at TA-33 on July 25, 1958. It was estimated that 13,000 curies were lost.	Air Release	4057	20
10/28/1958	A fire was detected on October 28, 1958 in pit #6 of the contaminated dump.	Fire	4057	27
11/6/1958	On November 6, 1958 K Division members were removing a plutonium pilot plant from the air filter building, contamination was spread to the floor, wheels of the fork lift, and the dirt east of the building.	Contam. Event	2510	3
12/8/1958	RaLa shot # 233 took place at 1545 hours. The shot involved 1305 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 1.4 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1600; background activity was 0.03 mR/h. Fallout was encountered, twice background, in the “new housing area” (Barranca Mesa), and 1.0 mR/h was recorded at the end of Tank Mesa (Barranca Mesa, overlooking the firing site). Back on the clockwise perimeter survey route, fallout was encountered 1.2 miles east past the Sportsman's Club, with a maximum of 1.4 mR/h recorded at the Guaje Canyon gate. The remainder of the survey route showed background activity.	RaLa Shot	2	all
12/30/1958	On December 30, 1958 there was a criticality incident involving 3.27 kg Pu $Pu0_2(N0_3)_2$ in ~168 liters of water. The cylinder contained dissolved Pu, when the agitator was stared it created critical geometry. One death resulted from the accident. 1.5×10^{17} total fissions were involved.	Criticality	6206	all
2/20/1959	RaLa shot # 234 took place at 1335 hours. The shot involved 1250 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.18 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1405; background activity was 0.04 mR/h. Fallout was encountered 0.5 miles past the Sportsman's Club and continued for 2 miles, with a maximum of 0.18 mR/h recorded at Booster #2, which is 1.2 miles east of the Sportsman's Club.	RaLa Shot	2	all
3/13/1959	RaLa shot # 235 took place at 1405 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 20 to 100 lbs. No radiation was detected. The team left the Administration Building (SM-43) at 1426; background activity was 0.05 mR/h. The team completed the counterclockwise survey; all readings showed background activity.	RaLa Shot	2	all

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
3/17/1959	On March 17, 308 curies of tritium were released to the outside when a valve on a Van de Graff was left open.	Air Release	2739	3
4/1/1959	During processing of irradiated U-235 at TA-48 uranium oxide was blown out of the hood when a sample can was opened.	Explosion	2514	4
4/2/1959	RaLa shot # 236 took place at 1635 hours. The shot involved 980 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the ESE. The maximum radiation measured at distance was 0.6 mR/h at 3 miles. The team left the Administration Building (SM-43) at 1750 to conduct a clockwise survey; background activity was 0.03 to 0.04 mR/h. Fallout was encountered at the intersection. The fallout continued west along State Road 4 for 3 miles, with a maximum of 0.6 mR/h recorded 1.5 miles west of the Guaje/State Road 4 intersection (12 mR/h was recorded at an isolated spot). The remainder of the survey showed background activity. The cloud was observed to go over the north Bayo Canyon wall.	RaLa Shot	2	all
4/14/1959	RaLa shot # 237 took place at 1250 hours. The shot involved 1140 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.4 mR/h at 1.7 miles. The team left the Administration Building (SM-43) at 1401; background activity was 0.03 to 0.04 mR/h. Fallout was encountered 1.2 miles past the Sportsman's Club, and readings remained elevated to the White Rock junction on State Road 4. A maximum of 0.4 mR/h was recorded 2 miles past the Sportsman's Club.	RaLa Shot	2	all
5/1/1959	During the operation of LAMPRE II radioactive gas was released through the exhaust system, causing an increase in background levels around the town site. High background levels were detected in the water boiler reactor room due to a disconnected exhaust pump in the valve house, the incident increased background levels around the town site.	Air Release	2515	4
5/15/1959	RaLa shot # 238 took place at 1547 hours. The shot involved 1040 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ESE. The team left the Administration Building (SM-43) at 1640; background activity was 0.03 to 0.05 mR/h. A clockwise survey was conducted; only background activity was recorded until fallout was encountered on the Main Hill Road 0.8 miles east of the main gate for about 0.6 miles. A maximum of 1.5 mR/h was recorded beyond the East Gate Laboratory at the entrance to the Camp Hamilton Trail. Because the cloud was reported to go down canyon (east-southeast), the readings are not believed to be related to the Bayo Canyon activity. During this period, a large 120-curie cobalt-60 source located about 400 feet directly north of the Main Hill Road at the East Gate Laboratory (TA-19) was in intermittent use and is believed to explain these readings (see also shots #240 and #242).	RaLa Shot	2	all
6/4/1959	RaLa shot # 239 took place at 1527 hours. The shot involved 995 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The maximum radiation measured at distance was 0.4 mR/h at 2.7 miles. The team left the Administration Building (SM-43) at 1630; background activity was 0.04 mR/h. During the clockwise survey, above-background activity was encountered at Booster #1, 3 miles east of the Sportsman's Club. It continued for 1.4 miles, with a maximum reading of 0.4 mR/h recorded 3.8 miles past the Sportsman's Club.	RaLa Shot	2	all
6/26/1959	RaLa shot # 240 took place at 1400 hours. The shot involved 954 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.12 mR/h at 2.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1419; background activity was 0.02 mR/h. Fallout was encountered at the Guaje pumice mine and continued for 1.6 miles, with a maximum of 0.12 mR/h recorded 0.8 miles past the mine. Fallout was encountered again on the Main Hill Road 1.3 miles east of the main gate, with a maximum of 1.3 mR/h recorded 0.5 miles east of the gate. Because the cloud was reported to have gone over the north wall of Bayo Canyon, this reading is again attributed to the gamma source at the East Gate Laboratory (see shots #238 and #242).	RaLa Shot	2	all
7/15/1959	On July 15, 1959 a fire broke out in a plutonium contaminated CWS exhaust filter during welding of a new section of exhaust duct on the discharge side of the filter unit.	Fire	19	55
7/15/1959	On July 15, 1959 a fire broke out in a plutonium contaminated CWS exhaust filter in Room 501 DP West. Highly contaminated ash was dispersed through out the room. The clothes of 12 firemen were held for decontamination.	Fire	2425	5, 6

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/17/1959	Tritium gas was released from a storage tank reservoir in Building 86 at TA-33 on July 17, 1959. Road blocks were established and 69 people were evacuated from the area. No appreciable radiation was measured outside the fence of Building 86.	Air Release	2425	5, 6
8/14/1959	On August 14, 1959 a tritium leak occurred at P-9 Van de Graff area when an "o" ring allowed tritium to be released.	Air Release	2426	3
10/7/1959	RaLa shot # 241 took place at 1438 hours. The shot involved 893 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The wind speed was 12 mph. The maximum radiation measured at distance was 0.12 mR/h at 3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1603; background activity was 0.05 mR/h. Questionable activity (only 0.01 mR/h over background) was encountered at Booster #1 for 4.2 miles, with a maximum of 0.12 mR/h recorded 1.5 miles past the Guaje pumice mine. During the remainder of the survey, only background activity was recorded.	RaLa Shot	2	all
10/14/1959	Explosion occurred while disposing of scrap and waste explosives	Explosion	NA	58
12/3/1959	On December 3, 1959 a fire broke out in an incinerator dry box exhaust system. A neoprene duct connection had burned out releasing contamination to the roof.	Fire	19	57
12/3/1959	On December 3, 1959, a fire broke out in the duct work of Room 313 of DP West where uranium materials are incinerated. The damage was limited to the duct work.	Fire	2494	3
12/3/1959	A fire occurred on December 3, 1959 in the drybox exhaust ductwork in Room 313 of DP West during the burning of U-235 contaminated rags. The exhaust stack discharged black smoke toward the west for approximately 15 minutes. Alpha contamination was detected downwind of Room 313.	Fire	4058	1
12/16/1959	On December 16, 1959 a filter in the vent line of the neutralization tank at the waste treatment operation at DP West failed allowing plutonium and americium to run down the roof and contaminate the ground.	Liquid Release	2494	3
1/15/1960	On January 15, 1960 in Room 308 of DP West a bottle containing plutonium solution had shattered. Contamination was tracked into the main hallway and into Room 206 and 363. Airborne contamination spread into 313, 322 and 326. the air supply room on the south side of Building 3 was monitored and found to be highly contaminated.	Liquid Release	3971	18
2/3/1960	Two different explosions occurred in the rag incinerator in Room 313 of DP West on January 28, 1960 the other on February 3, 1960.	Explosion	2496	3
2/3/1960	On February 3, 1960 in Room 313 of DP West an explosion occurred during the burning of U-235 contaminated rags. The area was monitored and no surface contamination was detected.	Explosion	3971	14
3/8/1960	RaLa shot # 242 took place at 1648 hours. The shot involved 908 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the S. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1717; background activity was 0.03 mR/h. Since the cloud was observed to travel down canyon, the activity that was encountered 1.7 miles east of the airstrip and continued for about 0.5 miles, with a maximum of 1.5 mR/h recorded 1.9 miles past the airstrip, is believed to be due to the gamma source at the East Gate Laboratory (see shots #238 and #240 above). The remaining readings, beginning about 1.5 miles west of Roy's Service Station (Totavi) and continuing for about 1.3 miles, are attributable to this shot. A maximum reading of 0.4 mR/h was recorded 0.9 miles west of Roy's Service Station.	RaLa Shot	2	all
4/13/1960	On April 13, 1960 in Building HP 21 there was widespread plutonium contamination when 100mg of plutonium was released during an experiment.	Contam. Event	2498	4

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
5/4/1960	RaLa shot # 243 took place at 1618 hours. The shot involved 957 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The maximum radiation measured at distance was 1.3 mR/h at 2.1 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1645; background activity was 0.02 to 0.03 mR/h. Fallout was encountered 0.7 miles west of Well #1 and continued for 2.5 miles, with a maximum of 1.3 mR/h recorded 1.3 miles past Well #1. At Well #1, a particle was collected reading 1100 mR/h at "contact" with a Cutie Pie (an ionization chamber instrument). Background readings during this survey seemed to fluctuate. The environmental group reported results of two film badge dosimeters planted at the airstrip, about 1 mile southwest of the firing site, for a period beginning 22 days before and ending 30 days after this shot. They reported the readings averaged 200 mR/mr over this period and attributed the dose to a possible particle from the main cloud, although the main cloud went in the opposite direction.	RaLa Shot	2	all
6/17/1960	On June 17, 1960 there was a criticality incident involving ~48 kg U-235. Uranium cylinders in thick graphite (9-in.) reflected before complete assembly, resulting in trivial damage. 6 x 10^{16} total fissions were involved.	Criticality	6206	all
9/1/1960	RaLa shot # 244 took place at 1300 hours. The shot involved 1120 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N and NW. The maximum radiation measured at distance was 0.3 mR/h at 1.2 miles; 0.3 mR/h at 2 miles. The team began a clockwise perimeter survey from the Administration Building (SM-43) at 1325; background activity was 0.05 mR/h. Fallout was encountered 0.8 miles east past the Sportsman's Club and continued for 0.8 miles, with a maximum of 0.3 mR/h recorded 1.1 miles past the Sportsman's Club; 2.1 miles west up Guaje Canyon the maximum was 0.3 mR/h. A resurvey the next morning found a "speck" reading of 1.1 mR/h at "contact" on Guaje Road, where the maximum reading was found the day before.	RaLa Shot	2	all
9/14/1960	September 14, 1960 15-30 gallons of americium raffinate spilled from a tank at Building 35 DP West. A trailer and the ground outside of the americium treatment Building were contaminated and cleaned.	Liquid Release	2429	5
9/16/1960	On September 16, 1960 approximately 15-30 gallons of Am raffinate spilled in Building 35 DP West. The equipment trailer and the south side of the Building and ground surrounding the trailer were contaminated.	Liquid Release	3971	8
9/21/1960	On September 21, 1960 a small explosion occurred in the Room 201 incinerator. The room was decontaminated the following day.	Explosion	3971	7
10/11/1960	RaLa shot # 245 took place at 1408 hours. The shot involved 1100 Ci of RaLa with an explosive charge of 20 to 100 lbs. The team started a survey on Barranca Mesa, completing a clockwise route. All readings were recorded as "00."	RaLa Shot	2	all
11/22/1960	RaLa shot # 246 took place at 1214 hours. The shot involved 1475 Ci of RaLa with an explosive charge of 101 to 200 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
2/17/1961	RaLa shot # 247 took place at 1650 hours. The shot involved 7090 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
3/24/1961	On March 24, 1961 a contamination incident occurred during the disassembly of a drybox on a milling machine. The turntable was taken to the contaminated truck for wrapping. The turntable was opened to facilitate further wrapping and in doing so some plutonium dust was released. A strong gust of wind blew spread contamination to the truck, the adjacent building, and surrounding ground. A large airborne count of alpha contamination was measured in Building 54 during the incident.	Air Release	19	85
3/24/1961	On March 24, 1961, during removal of equipment at DP West an undetermined, but visible release of plutonium occurred.	Air Release	2520	4
3/24/1961	On March 24, 1961 a contamination incident occurred in Building 54 of DP Site, resulting in the spread of plutonium dust contamination. The incident occurred during the removal of a glove box from a milling machine.	Air Release	4059	15
5/19/1961	RaLa shot # 248 took place at 1314 hours. The shot involved 3902 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
6/20/1961	RaLa shot # 249 took place at 2019 hours. The shot involved 5300 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
8/7/1961	On August 7, 1961 a container with a uranium fuel element leaked. Contamination products were detected in the parking lot and around the building. No decontamination was done.	Air Release	2524	4
9/28/1961	On September 28, 1961 a spill occurred in the liquid waste sampling room located in the northeast of Building 2, DP West. The drain line stopped up and contaminated liquid flowed down the storm drain. Workmen from Room 326 had walked through the area. Their homes and personal shoes were monitored and no contamination was detected.	Liquid Release	4059	10
10/11/1961	RaLa shot # 250 took place at 1302 hours. The shot involved 3870 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
11/17/1961	RaLa shot # 251 took place at 1430 hours. The shot involved 4150 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
11/28/1961	On November 28, 1961 a spill was discovered on the ground north of the pump house of Building 700. The spill was monitored and contamination was found.	Liquid Release	4059	4
12/10/1961	The GNOME nuclear test, the first test in the Plowshare Program, was conducted near near Carlsbad, NM. The device was placed at a depth of 1,185 ft in a shaft drilled in salt. The objectives of the 3 kiloton test were isotope recovery, neutron physics experimentation, examination of heat recovery, seismic measurements, and explosive development. The shot also had a Vela Uniform Program objective to determine how the seismic signals and effects of a 3-kiloton device detonated underground in salt beds differed from the outputs of detonations of different yields in other geologic formations such as tuff and granite and from signals caused by earthquakes. [Ref: http://www.nv.doe.gov/library/films/fulltext/0800034.htm and https://www.osti.gov/opennet/reports/plowshar.pdf]			
1/30/1962	RaLa shot # 252 took place at 1908 hours. The shot involved 6077 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
2/2/1962	RaLa shot # 253 took place at 1341 hours. The shot involved 1590 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
3/6/1962	RaLa shot # 254 took place at 1330 hours. The shot involved 5940 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.	RaLa Shot	2	all
3/9/1962	On March 9, 1962 .8 g of tritium were released into the atmosphere during an experiment at TA-41.	Air Release	4060	8
12/11/1962	On December 11, 1962 there was a criticality incident involving U-235 foils in graphite. The assembly went critical when it was ran due to inadequate communication between work crews. 3×10^{16} total fissions were involved.	Criticality	6206	all
2/27/1963	On February 27, 1963 approximately 48 millicuries if radioactive iodine was release out the stack of Cell 9, Wing 9, CMR Building.	Air Release	4061	18
3/4/1963	On March 4, 1963 radioactive I-131 was released from Stack #2.	Air Release	2072	150
4/8/1963	On April 8, 1963 there was a uranium spill at TA-46.	Contam. Event	2536	2
6/1/1963	A glovebox was torn in a drybox at DP West during a routine operation, releasing plutonium into air.	Fire	2538	3
6/1/1963	During maintenance, a spark from a welding operation started a fire in the filter of a plutonium drybox, releasing plutonium into air.	Fire	2538	3
6/6/1963	On June 6, 1963 a fire occurred in a drybox air intake filter in Room 213 of DP West. No contamination was detected in the vicinity of the drybox.	Fire	4061	16
7/31/1963	On July 31, 1963 an employee spilled some contaminated material from a U-235 rag incinerator onto the hood and floor of Room 313 DP West.	Contam. Event	4061	9

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
11/15/1963	On November 15, 1963 P-9 accidentally released 2 cc of tritium gas.	Air Release	2502	4
11/26/1963	On November 26, 1963 a worker was found to have contamination on his clothing. His personal car and home were monitored and no contamination was found.	User Error	4061	2
1/10/1964	On January 10, 1964 in SM-66 depleted uranium residue ignited in a drum. The material was allowed to burn out.	Fire	2812	3
2/11/1964	Omega Site was contaminated when a sample reading 4.5 R/hr at 1 m was removed from OWR vertical port and dragged down the road (because of its weight) to the storage area.	Contam. Event	2812	3
4/12/1964	An explosion occurred in Room 313 rag incinerator drybox following ignition of a batch of U-235 contaminated rags on April 12, 1964. The fire spread from the drybox into the adjoining hood and ignited another batch of rags. The fire was quickly extinguished.	Explosion	11	297
4/22/1964	An explosion occurred following a fire in Room 313 DP West from uranium contaminated rags on April 22, 1964. The fire spread from the drybox to the adjoining hood.	Fire	2505	4
4/22/1964	On April 22, 1964 an explosion occurred in an incinerator drybox in Room 313 of DP West during the incineration of U-235 contaminated rags.	Explosion	4062	5
7/2/1964	Explosion attributed to accumulation of unburned gas in area of stagnant air movement in furnace upper passageways, damaged boiler furnace	Explosion	NA	78
7/31/1964	On July 31, 1964 high levels of contamination were detected in a hood after an accidental plutonium release. The hood was decontaminated, but the stack was likely contaminated.	Air Release	2507	4
10/3/1964	On October 3, 1965 there was a tritium release at P-9. Approximately 100 curies of tritium was released.	Air Release	4063	3
11/11/1964	On November 11, 1964 there was a fire in pit 3 of area G (Mesita del Buey). The cause of the fire is unknown.	Fire	4062	5
2/16/1965	On February 16, 1965 approximately two liters of tritium gas were released up the stack during an experiment.	Air Release	4063	12
2/17/1965	On February 17, 1965; 10 curies of tritium was released into Room 4130 during an experiment.	Air Release	2072	261
2/17/1965	An estimated 10 Ci of tritium were released on February 17, 1965 from the hood in Room 4130 of CMF-4.	Air Release	4063	12
4/14/1965	On April 14, 1965 in Building 35 sludge filtering room, approximately 25 gallons of contaminated sludge spilled when a pipefitter disconnected a flange in the sludge filtering tank. The area was quickly decontaminated.	Liquid Release	4063	12
5/28/1965	On May 28, 1965 at White Sands Missile Range there was a criticality incident involving 96 kg enriched U-Mo alloy, due to incorrect operation. The assembly bolts broke, and there was minor damage to coating. 1.5×10^{17} total fissions were involved.	Criticality	6206	all
6/1/1965	At DP East the gas purge line to a recovery furnace became plugged. The operator in charge removed a rubber hose connected to the unit, and uranium-containing dust was blown out into his face and onto his clothing.	User Error	NA	2
12/1/1965	During the removal of a rod coated with Am-241 from an experimental apparatus, personal clothing of the operator was contaminated.	User Error	NA	4
4/15/1966	On April 15 and 16, 1966 there was a "large spill" of tritium at P-9 due to a diaphragm failure.	Air Release	4064	6
5/11/1966	An explosion occurred in a rag incinerator globe box in the U-235 recovery area at DP West. The explosion cracked the window of the glove box.	Explosion	NA	4-5
6/9/1966	On June 9, 1966 there was a tritium spill at P-12.	Air Release	4064	6
11/16/1966	The air cleaner at one of the enriched uranium shops developed a pin-hole leak, which resulted in high surface contamination of the surrounding area.	Air Release	NA	3

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/14/1967	A fire occurred on July 14, 1967 in Room 313 of DP West. Sparks from the incinerators escaped and ignited the pre-filter located in a well in the loading drybox floor. The flames swept up the exhaust line and ignited the HEPA filter in the drybox. The Building 3 roof was monitored and no contamination was detected.	Fire	4065	10
12/1/1967	An explosion occurred in the rag-incinerator drybox in Room 313 DP West on Dec. 1, 1967 during the incineration of U-238 contaminated rags.	Explosion	NA	4
12/10/1967	The GASBUGGY nuclear test was conducted in the San Juan Basin, 55 miles east of Farmington, New Mexico. The device was placed at a depth of 4,240 ft in a shaft drilled in a gas-bearing sandstone formation. The objective of the test was to investigate the feasibility of using nuclear explosives to stimulate a low-permeability gas field. GNOME was the first Plowshare joint government-industry nuclear experiment to test an industrial application. [Ref: https://www.osti.gov/opennet/reports/plowshar.pdf]			
1/1/1968	In early January 1968 members of group J-11 were working with Pb-210 at TA-48. During routine monitoring one employee's shoes were found to be contaminated. The homes of several employees were monitored and one was found to be contaminated. The home was decontaminated.	Contam. Event	4066	12
2/1/1968	Four days after a Pb-210 spill in February 1968, Pb-210 contamination was detected in the home of an employee, the area was decontaminated.	Contam. Event	817	13-14
2/7/1968	On February 7, 1968 approximately 100 cc of tritium gas was released in Room 4136 Wing 4 of CMR Building.	Air Release	4066	36
2/8/1968	100 cc of tritium gas may have been released from the exhaust system to the environment on February 8, 1968.	Air Release	1180	8
3/1/1968	An employee broke a charcoal trap which contained approximately 100 cc of tritium, which was released into the exhaust system In March of 1968.	Air Release	817	13
4/26/1968	At TA-48 some Pb-210 was spilled on the floor and tracked out of the laboratory. The spill was not detected until 4 days later when Pb-210 was detected during routine surveys. One home had spots reading up to 1500 cpm of alpha radiation on the rug. The rug in the home was removed.	Contam. Event	NA	5
6/4/1968	The sidewalk, driveway, and rug in the home of an employee were contaminated with Pb 210 sometime around June 14, 1968.	Contam. Event	4066	10
9/17/1968	There was an air duct fire in Building 3 between the exhaust blower near Room 313 and the main stack at DP West on September 17, 1968. The fire was due to a welding operation.	Fire	817	2-3
9/17/1968	On September 17, 1968 there was a fire in Building 3 main exhaust duct of DP West. No contamination was detected on the roof or duct work.	Fire	4066	2
1/2/1969	On January 2, 1969 a contamination accident occurred in Room 606 DP West resulting in the release of plutonium dust.	Contam. Event	NA	6-7
1/15/1969	A glovebox explosion occurred in the uranium recovery operation at DP West, during the incineration of U-235 metal turnings.	Explosion	NA	3
1/15/1969	During the removal of Pu-239 contaminated waste materials from a glovebox line at DP West, the transfer bag ruptured.	Explosion	NA	3
2/27/1969	On February 27, 1969 a fire occurred in the #2 glovebox line in Room 500 DP West, resulting in the release of plutonium dust contamination.	Fire	NA	6-7
3/3/1969	On March 3, 1969 a fire occurred in the leaching hood in Room 313 DP West, during leaching of U-235 contaminated filter frames.	Fire	NA	6-7
3/25/1969	On March 25, 1969 an explosion occurred in the glovebox of Room 313 DP West. The explosion blew out U-235 dust contamination into the Room.	Explosion	NA	6-7
6/26/1969	On June 26, 1969 an explosion occurred in the rag incinerator box in Room 313 DP West during the burning of U-235 turnings. The explosion scattered contamination through out the room.	Explosion	NA	5

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Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
8/21/1969	On August 21, 1969 approximately 5.73 liters of tritium gas was released into the atmosphere at TA-33.	Air Release	4067	4
10/1/1969	"High levels" of airborne plutonium were detected in the room when a CMF-5 employee dropped a plutonium containing sample.	User Error	4182	3,4
10/14/1969	On October 14, 1969 plutonium dust was released from a trash bag during the transfer from a glovebox in Room 308 DP West.	Air Release	4182	3
10/14/1969	On October 14, 1969 a contamination incident occurred in Room 308 DP West, resulting in the release of plutonium dust contamination. The incident occurred during the transfer of trash from a glove box in a plastic bag. The bag ruptured resulting in the contamination of the floor. A CMF-5 staff member accidentally dropped a container with plutonium inside. The lid of the container cam off resulting in a high level of airborne Pu contamination.	Air Release	NA	4-5
1/16/1970	On January 16, 1970 ZIA craftsmen pumped a caustic solution into the negative water pressure circulating tank in the Building 150 stairwell DP West. Highly contaminated foam escaped through a vent pipe, contaminating the tank, grill, west wall, and stairwell.	Liquid Release	NA	7
4/3/1970	On April 3, 1970 a furnace containing uranium exploded releasing dust in SM-35 Room 104.	Explosion	4261	1
6/10/1970	On June 10, 1970 a tri-state tractor trailer was found to be contaminated with Co60. The trailer was decontaminated, but the source of the contamination is a mystery.	Contam. Event	NA	4
7/1/1970	A minor fire occurred in the hood of a rag incinerator in Building 3 of TA-21 which was associated with recovery of U-235 oxide.	Fire	NA	4
7/1/1970	On May 1, 1970 a ruptured exhaust filter allowed for an increase in air activity. The filter was replaced and no background contamination was found outside of SM-35.	Air Release	NA	4
9/17/1970	On September 17, 1970 a fire started in a dust collection jar of a vacuum in Room 104 of TA-3-35. The fire started as a result of a spark during the cutting of U-235 fuel elements.	Fire	NA	9
10/7/1970	On October 7, 1970 a capillary tube containing $^{238}PuO_2$ broke in an open-faced hood in Room 605a of Building 150 of DP West. The hood exhausted directly to the roof without filtration. The room under the stack was contaminated in an area of approximately 100 square feet. Areas of contamination were found on the roof of the office trailer parked northwest of Building 150. No other contamination was found. The areas were decontaminated.	Air Release	4068	6
10/7/1970	A sample of radioactive tritiated salt was lost at Los Alamost Scientific Laboratory. The sample was reported missing 9-29-70 after routine inventory. An exhaustive search failed to turn up the missing sample.	User Error	NA	120
3/29/1971	On March 29, 1971 a worker was emptying a dempster dumpster in pit 6, area G, TA 54 when a strong gust of wind blew contamination onto the truck and the container.	Air Release	3972	106
3/29/1971	On March 29, 1971 Pu238 became airborne during the unloading of a dumpster containing radioactive waste at the disposal pit. The truck carrying the waste was contaminated and the contamination did not escape the disposal pit.	Air Release	4705	4
3/29/1971	On March 29, 1971 during the emptying of a dumpster of radioactive waste at TA-54 Pu-238 became airborne and contaminated the truck carrying the dumpster. The decontamination did not escape the disposal pit.	Air Release	NA	5
7/31/1971	On July 31, 1971 Pu 238 was released during the disassembly of a transit heat source containing 26,092 Ci of plutonium. Some contamination was released into Wing 9 of CMR Building. 55 microcuries escaped the building over a period of 16.5 hours.	Air Release	3972	5
7/31/1971	On July 31, 1971 employees were working with a capsule containing Pu-238 in Room 9130, Wing 9, CMR Building. Contamination was released into the room and the workers were contaminated.	Contam. Event	5442	1
10/7/1971	On October 7, 1971 a release of Pu-238 oxide occurred in 605 DP West contaminating 200 sq ft of the building, the roof and the surrounding ground.	Contam. Event	NA	6
10/15/1971	There was a fire in exhaust filter SM-102 on October 15, 1971.	Fire	1417	3
11/2/1971	On November 2, 1971 an explosion in test cell furnace blew uranium contamination onto floor.	Explosion	1417	3

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
12/17/1971	On December 17, 1971 high Pu-238 air counts were detected due to contamination from an exploding bottle.	Explosion	1417	3
8/1/1973	XO-2 cooling loop leaks at TA-53 allowed 1.5 Ci of tritium to be transferred along with 25,000 L of waste water from the waste tanks in the experimental area to the sewage lagoons at TA-53 between July 1, 1978 and September 30, 1978.	Air Release	NA	32
7/9/1974	On July 9, 1974 it was discovered that a pipe conveying radioactive wastes to TA-50 was leaking north of Pajarito road east of TA-3-184. The section of pipe was repaired.	Liquid Release	515	6
8/14/1975	On Aug. 14 approximately 10 gallons of reactor water went down the drain to the dry creek bed.	Liquid Release	392a	16
8/27/1975	On Aug. 27, 1975 approximately 960 gallons of regenerate material spilled out of a sludge holding tank contaminating Room 60A, TA-50. Approximately 500-700 gallons was lost outside. The solution contained Cs, Pu, St, Am. The spill area was roped off, covered with wet sand to minimize airborne contamination, and cleaned.	Liquid Release	392a	15
1/1/1976	In 1976 approximately 3271 Ci of tritium was release into the environment (this does not include 22,000 Ci released from TA-3-34 on July 15, 1976).	Air Release	NA	13
7/15/1976	On July 15, 1976 there was a tritium release from TA-3-34 of 22,000 Ci.	Air Release	NA	15
1/1/1977	In 1977 approximately 6417 Ci of tritium was released into the environment (this does not include 30,800 Ci released from TA-33-36 on October 6, 1977).	Air Release	NA	13
10/6/1977	On October 6, 1977, 3.08 $x10^{10}$ μCi of tritium gas was released from Room 9 TA-33-86 due to a loose high pressure fitting. Averaged over 24 hours the stack concentration was 0.104 uCi/ml.	Air Release	1232	5
10/6/1977	On October 6 1977 there was a tritium release from TA-33-86 of 33,217 Ci.	Air Release	NA	18
10/6/1977	On October 6, 1977 there was a tritium release of 30,800 Ci from TA-33-86.	Air Release	NA	15
11/11/1977	On November 11, 1977, at TA-54 Burial Pit seven bales of suspect low-level radioactive contaminated combustible waste auto-ignited. Apparent cause was a bottle, or bottles of acid improperly disposed of in the combustible waste.	Fire	NA	22
8/22/1978	On August 22, 1978 SM-102 a drum of depleted U-238 chips ignited while being moved to the outside.	Fire	NA	18
10/30/1978	It was discovered on October 30, 1978 that a large amount of tritium was released when a glass ballast valve was left open.	Air Release	3462	3
12/1/1978	An LASL employee contaminated the sleeve of his shirt, which was not detected until the employee returned to work following day. No contamination was detected at his home or in his automobile.	User Error	NA	10
5/4/1979	On May 4, 1979 approximately 3000 Ci of tritium was released from SM-34.	Air Release	3462	102
5/4/1979	A stainless steel pot containing uranium tritide was overheated in a laboratory at the Cryogenics Building and ruptured on May 4, 1979. tritiated water escaped into the laboratory because of inadequate air flow in the hood. Some tritium was released to the atmosphere.	Liquid Release	4484	1-2
5/4/1979	On May 4, 1979 there was a tritium release of ~3,000 Ci from TA-3-34.	Air Release	NA	18
5/7/1979	Tritium exposure incident at SM-34 on May 4, 1979.	Contam. Event	NA	4
5/18/1979	On May 18, 1979 during the transfer of 1500 gallons of contaminated water from the north holding tank to LAMPF Site sewage lagoons. The area A parking lot and area A shop floor were flooded, procedures to prevent the spread of contamination were used and the areas were quickly decontaminated.	Liquid Release	4154	91
5/25/1979	On May 25, 1979 approximately 3000 Ci of tritium were released from SM-34.	Air Release	4154	94
8/22/1979	On August 22, 1979 approximately 200 grams of UF6 was released at Building 23 TA-18 Pajarito Site. Approximately 0.0038 grams was released into the environment. The majority of the ~200 grams (~180 grams) was caught in the HEPA filter.	Air Release	4154	20
9/17/1979	A dempster dumpster fire occurred at TA-33-86 on September 17, 1979. The only radioactive isotope believed to be present at the time of the fire was tritium.	Fire	4154	6

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
12/12/1979	On December 12, 1979 150 to 200 gallons of slightly radioactive primary reactor system water was released at TA-2 inside Building 44. Approximately 50 gallons drained to a nearby creek via a floor drain in Building 44.	Liquid Release	4154	1
11/1/1980	In November 1980 there was a release of 16 curies of tritium gas and a total of 10 minor radiation releases of plutonium in labs reported internally.	Air Release	933	19
2/1/1981	In February 1981 a total of 11 minor radiation accidents were reported internally.	Contam. Event	936	17
3/19/1981	On March 19, 1981 liquid from an industrial waste line serving TA-48 was inadvertently pumped into Mortandad canyon.	Liquid Release	NA	128-129
3/24/1981	On March 24, 1981 several curies of gaseous tritium were released from the Van de Graaff Building at TA-3.	Air Release	NA	128-129
10/14/1981	On October 14, 1981 ten samples contaminated with PuO2 were opened in a laboratory where Pu is not normally handled. Contamination was spread into several laboratories, a small shop, the analyst and several other workers before it was detected. One vehicle and two homes were contaminated with a small amount of material. All employees and contaminated areas were readily decontaminated.	Contam. Event	2057	8
10/14/1981	plutonium contamination incident at TA-3, SM-29, October 14, 1981.	Contam. Event	NA	35
11/1/1981	In November 1981 ten minor radiation releases were documented and investigated internally at LANL.	Contam. Event	935	20
3/19/1982	On March 19, 1982 a section of the industrial waste line carrying fission products from hot cells serving TA-48 had been found leaking. A limited area of soil was contaminated within Laboratory boundaries. The affected soil from the areas along both sides of the road behind TA-48 were removed (down to bedrock) up to the edge of Mortandad Canyon, and replaced with clean soil.	Liquid Release	4412	1
8/10/1982	On August 10, 1982 a furnace at TA-55 ignited and over pressurized a glovebox. Two glovebox windows ruptured releasing alpha contamination into the room and adjacent corridor.	Air Release	NA	6
11/2/1982	On November 2, 1982 approximately 50-100 liters of waste liquid escaped from a tank vent at TA-21-257 contaminating the building roof, walls, and surrounding area with low levels of plutonium, americurium, and uranium.	Liquid Release	NA	6
1/10/1983	An accidental release of chromium oxychloride occurred at the Van de Graaff facility on January 10, 1983. The accident occurred when an employee removed a valve from one end of a pipe which allowed for the liquid stored in the pipe to spill on the floor.	Liquid Release	NA	4
6/1/1983	On June 1, 1983 high airborne plutonium levels were detected in Room 429 at TA-55 Building PF-4. The high levels were caused by a leak in the dry vacuum line to a glovebox.	Air Release	NA	1
6/1/1983	Radiation material was discovered in the salvage yard and reported during the report period.	Contam. Event	NA	4
8/25/1983	On August 25, 1983 a puff release of 104 Ci of tritium occurred at TA-33. This was followed by a slow release of an additional 45 Ci in the subsequent 24 hour period.	Air Release	NA	4
11/28/1983	On November 28, 1983 a fire occurred in the well house at Pajarito water supply well no. 2. Two large PCB capacitors were involved in the fire emitting PCB when the heat caused them to rupture releasing their contents. Air and ash samples confirmed significant PCB contamination inside the building.	Fire	NA	3-4
12/6/1983	On December 6, 1983 two plutonium containing shipping containers were inadvertently opened, contaminating the clothing and skin of eight workers.	Contam. Event	NA	3-4
2/17/1984	Fire at TA-50 Building 1 in a ventilation exhaust plenum on February 17, 1984, filter bags were ignited.	Fire	NA	6
4/10/1984	Hydrogen fluoride release on April 10, 1984 from Room 5096 at TA-3-29 through a hole in an exhaust flex hose of the gas centrifuge.	Air Release	NA	4-5
7/1/1984	There was a fire at the lithium hydride shop TA-3, SM-39 on June 6, 1984. Lithium hydride dust ignited in a section of exhaust duct.	Fire	NA	4-5

Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

Date of Incident	Description	Incident Type	Repos. No.	Initial Page of Interest
7/26/1984	Equipment failure to contain plutonium solution resulting in significant area contamination and high nose swipes for three employees on July 26, 1984 at TA-55-4-401.	Equipment Malfunction	NA	2-3
10/19/1984	Inadequate procedures when handling packaged Pu-238 resulted in widespread area contamination and contamination of personal clothing of two employees on October 19, 1984 at TA-54.	Contam. Event	NA	2-3
1/11/1985	On January 1, 1985 a failure to comply with established procedures resulted in a release of radioactive materials along a public roadway (report no. LAMPF-85-1).	Contam. Event	NA	6
6/1/1985	60 gallons of tri-methyl benzene were spilled in the neutrino area at the L.A. Meson Physics Facility, no serious injuries resulted form this accident.	Liquid Release	NA	6
6/12/1985	On June 12, 1985 the improper transfer of radioactive material resulted in an employee's home being contaminated (Report no. AHP-85-8).	Contam. Event	NA	6
7/1/1985	On July 1, 1985 activated cooling water was discharged outside facility (Report no. LAMPF-85-5).	Liquid Release	NA	6
9/12/1985	On September 12, 1985 there was a fire in a glove box at TA-55-4-429 which resulted in high airborne activity and area contamination (Report no. CHEM-HP-85-20).	Fire	NA	6
2/2/1986	On February 2, 1986 there was an unexpected release of tritium oxide at TA-41-4-236A.	Air Release	NA	11
10/30/1986	On October 30-31, 1986 an estimated 633 Ci of tritium were released at TA-33, mostly in the form of tritiated water.	Air Release	NA	8
11/14/1986	On November 14, 1986 11.5 Ci of tritium was released from TA-33 in the form of elemental tritium.	Air Release	NA	8
11/1/1987	Low level liquid waste from TA-55 showed higher than normal levels of plutonium in Nov. and Dec. There was a pinhole leak in a stream coil in a cascade dissolver process at TA-55	Liquid Release	NA	4
2/22/1988	On Feb 22, approximately 5800 Ci of tritium were released from TA-33.	Air Release	1246	8
2/27/1990	On February 27, 1990 cooling water overflowed in the exhaust system of TA-55-4.	Liquid Release	NA	8
3/1/2000	An incident occurred in March 2000 when eight workers at TA-55 were exposed to airborne plutonium.	Air Release	NA	1
3/1/2000	An incident occurred in 1998 when a worker at TA-55 was exposed to airborne plutonium.	Air Release	NA	1
5/4/2000	On May 4, 2000 a wild fire was ignited which ulitmately burned nearly 50,000 acres in and around Los Alamos New Mexico.	Fire	NA	1
7/27/2005	A small amount of americium-241 was found to have contaminated a package that was shipped from Los Alamos to Pennsylvania. The contamination was spread to homes in Colorado, Kansas, and New Mexico.	Contam. Event	6204	all

Chapter 17: Prioritization of Radionuclide Releases

The LAHDA team identified the following steps to be completed to prioritize radionuclide releases:

1) Review the history of operations at Los Alamos,
2) Find relevant data concerning air and liquid releases,
3) Correct or adjust older data with appropriate factors based on current state-of-the-art methods,
4) Fill in gaps in data with justifiable methods for estimation of air and liquid releases, and
5) Prepare a prioritized list of radionuclides for both operational and episodic releases.

The prioritization of historical releases focused on providing a relative ranking of radionuclide releases that may have impacted public health and to limit attention to radionuclides that did not impact human health. Prioritization to date has been accomplished using a method based on the volume of air or water required to dilute the radionuclide in question down to maximum effluent concentrations for public areas− this is defined to be "Priority Index". This simple method does not require the definition of a specific "receptor" nor does it require use of an exposure pathway model. For certain historical releases, namely airborne plutonium from DP West Site, it was determined that more developed evaluation based on the screening methods of National Council on Radiation Protection and Measurements (NCRP) Report No. 123 should be used (NCRP 1996). That screening evaluation is described in Chapter 18.

Priority Indices were calculated based on estimated quantities released and maximum effluent concentrations documented in Title 10 of the Code of Federal regulations, Part 20 (USNRC 2003). They are intended to be guidelines to determine the relative rank of a release in comparison with others. The prioritization methods described herein require that some estimates of quantities of each radionuclide or radionuclide class released to the environment be available. In some cases, these data are not available for all facilities or for all years of operations at Los Alamos.

The prioritization of releases from LANL has been problematic. During the Manhattan Project era and continuing well into the post-1946 AEC era, LASL did not measure many of their release points and did not systematically archive and compile effluent data. No effort has been made to characterize the magnitude of the releases from non-point source emissions that have been shown to be particularly important at other DOE sites such as Rocky Flats. Unlike most DOE sites, LANL's compilations contain well-documented effluent data for only the post Clean Air Act (post-1969) era. Only summary-level information for certain facilities is given in LANL's compilations prior to this period. In addition, potentially important release sources such as D Building (Fig. 17-1), which housed processing of plutonium during World War II and remained active until around 1953, were not subjected to stack sampling programs and have no effluent data available.

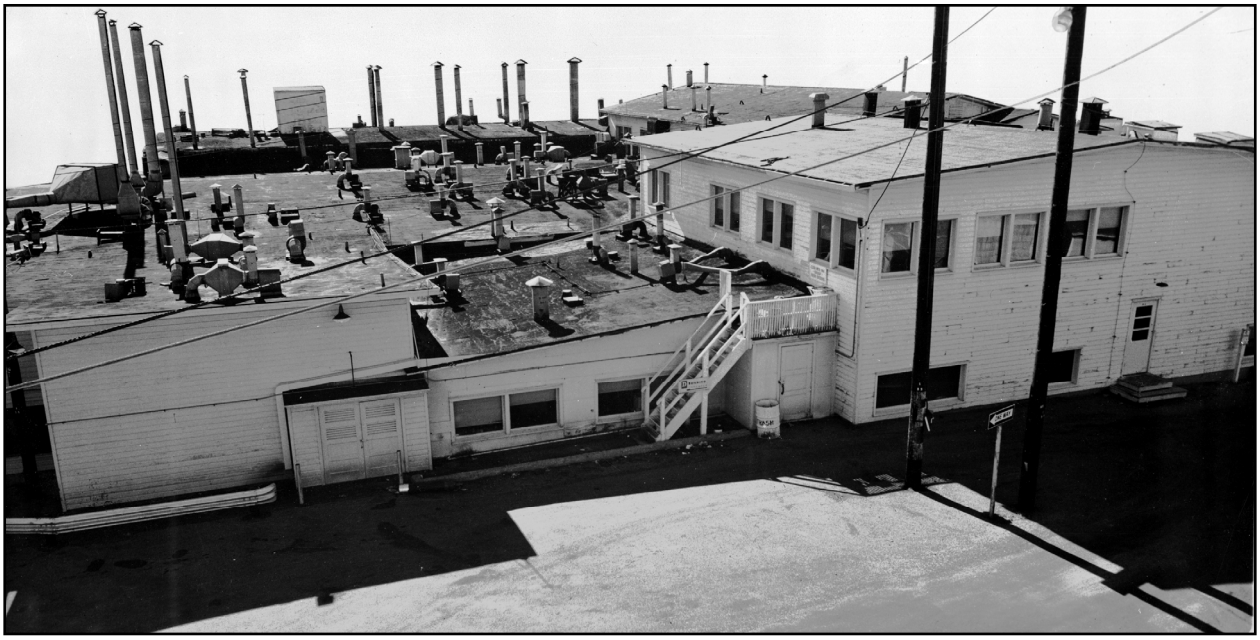

Fig. 17-1. The earliest plutonium processing at Los Alamos was conducted in this facility, known as D Building. Airborne effluents through approximately 85 rooftop vents were unmonitored and largely unfiltered. Photograph from the late 1940s.

Unlike any other AEC/DOE site studied thus far with regard to historical releases, there was nothing approaching a comprehensive compilation of releases available at LANL to establish a simple, initial prioritization. The best available compilation was one assembled in the early 1970s to support preparation of the first site-wide final environmental impact statement (FEIS) that LANL published in response to the requirements of the Clean Air Act (USDOE 1979). The LAHDRA team has found that compilation to have numerous errors and omissions. Despite these errors and omissions, the preliminary prioritization used data assembled for that report as well as other information, such as estimates of the quantities of uranium expended in explosive test shots, to augment the LANL compilation.

Prioritization of Airborne Radionuclide Releases

LANL operations started in 1943 and have continued to the present. In the early years, radiation science, environmental science, and occupational health were all disciplines that were in their infancy. As time progressed, LANL has, by their own volition and by pressure from the public and government, increased monitoring, documentation, and reporting.

Data Sources

There are six main data sources for the airborne radionuclide effluent information at LANL:

- (Andrews ca. 1973) – "Joe Graf Binders" 1 and 2– Two binders of documents assembled by LANL Environment, Safety, and Health (ES&H) staff for group leader Joe Graf in the early 1970s that document releases from LANL before 1973. This was done to support development of a draft

site-wide Final Environmental Impact Statement (FEIS). The FEIS was finally published in 1979. The documents assembled in these binders include records of room air concentrations, stack monitoring data, ES&H reports, and miscellaneous memos.

- (Miller 2001) - Scott Miller, also an ES&H group member, compiled stack release data from 1973 to 1990. These data were assembled in a three-ring binder that was shared with the LAHDRA team and entered into the LAHDRA project information database. A Microsoft Excel® spreadsheet file containing the associated data was also provided to the project team.
- (Dummer et al. 1996) – A detailed study of all the RaLa shots conducted in Bayo Canyon at Los Alamos and the quantities of RaLa involved in those explosives tests from 1944 to 1962.
- (Drake and Eyster 1971) – A memo that details estimated quantities of uranium that were expended in explosive testing at LANL from 1944 to 1970.
- (Jordan and Black 1958) – An article in the American Industrial Hygiene Association Journal that speaks of airborne radioactive effluents from LANL). This work is one of the most important early studies on releases. LANL has considered the Jordan and Black publication to be the best-available scientific data identified on possible early emissions. As discussed later in this chapter, the LAHDRA project team disagrees with that assessment.
- (Hyatt 1956) – A 1956 memorandum prepared by an alternate group leader of the LASL industrial hygiene group that documents results of a 1955-1956 study that yielded corrected plutonium release estimates for DP West Building 12 stacks on a monthly basis for 1948 through 1955.

Summary of Results for Prioritization of Airborne Radionuclide Releases

During the period of LANL's existence, many operations involving radionuclides have been performed, and effluents containing various radioactive constituents have been released. This section outlines the calculation of priority indices for six airborne radionuclide sets (plutonium, uranium, tritium, Radioactive Lanthanum (RaLa), Mixed Fission Products (MFP), and Mixed Activation Products (MAP)) for off-site airborne releases from LANL.

A Priority Index (PI) (in units of liters, L) for airborne radionuclide releases is calculated by computing the air volume required to dilute the annual activity released to be equal to the worst-case maximum effluent concentration per 10 CFR 20 (USNRC 2003). This priority index is intended to be a guideline to determine if a nuclide set requires further iterations of calculation and refinement, or if it warrants lower priority relative to other nuclides (O'Brien J. and Burmeister R. 2004). For example, a PI of 10^6 L indicates that 10^6 (or one million) liters of air would be required to dilute the released material to a

concentration equal to the maximum effluent concentration. The priority index does not consider environmental transport and dilution. Although the lowest available (most conservative) maximum effluent concentration is used, the priority index does not otherwise address uptake factors. It does not consider decay in transport, which means the priority index would tend to overstate the importance of short-lived materials. Within these limitations, it provides a simple tool for establishing the relative importance of various airborne releases.

For the years 1944 to the present, LANL summary data were reviewed to collect available information for air releases and inventories used in explosions. This effort did not include an independent source term reconstruction; rather it relied on LANL compilations of releases with some adjustments by the LAHDRA team. Not all the data compiled herein are measurements of stack releases. A Microsoft Access® Off-Site Releases (OSR) Database was created to tabulate the available information and to link it to existing LANL documents that have been located and assembled by the LAHDRA project team. In most cases, these documents are available as image files in Adobe Acrobat® Portable Document Format (PDF) files that are linked to records containing bibliographic information the LAHDRA DocSleuth database.

Radionuclide "Sets" and "Collections"

The summary data for airborne radionuclide prioritization is grouped by radionuclide "collections" or "nuclide sets" because of the conventions used by LANL staff in quantifying and reporting concentrations and releases. These "sets" are as follows: plutonium, uranium, tritium, Radioactive Lanthanum (RaLa), Mixed Fission Products (MFP), and Mixed Activation Products (MAP). Certain collections of nuclides are grouped in LANL documents. For instance, in many cases, effluent data reports have the radionuclides ^{239}Pu, ^{238}Pu and ^{235}U associated. In some cases no mention of the analysis type is made, and so the analysis result can be attributed to several nuclides. In these cases, the nuclide collection would have all of these radionuclides listed in it as a string. During the analysis, when separating the nuclides, "nuclide sets" were created that are simply the nuclide collection values that will be attributed to a nuclide such as plutonium. Plutonium has the lowest value for maximum effluent concentration, so if a nuclide collection contained both plutonium and uranium, then the value was counted for plutonium. This method was used to prevent both "double counting" the release and to assign the larger value to plutonium. This practice may overstate the importance of plutonium, particularly after the late 1970s. When the "nuclide set" was created for uranium, only those entries that did not contain plutonium isotopes were included.

Effluent Data for Plutonium: Plutonium data were obtained for calendar years from 1948 through 1996. Release estimates are not available for D Building. D Building started operation in late 1943/early 1944,

and continued to be used until around 1953. It is important to note that no airborne effluent data were included in LANL compilations for the years 1944 through 1947. In addition, the releases from DP Site reported by LANL for 1948, 1949, and 1950 are apparently based on simple estimates first made by Jordan and Black using methods that are not well documented (Jordan and Black 1958).

Airborne plutonium releases were prioritized based on values compiled for the 1979 FEIS and also documented in a 1975 publication (Maraman et al. 1975). Values for 1948–1955 were adjusted upward by the LAHDRA team (by roughly a factor of 20) to agree with results of a study conducted by the LANL industrial hygiene group in 1955 and 1956 and reported by Edwin C. Hyatt in 1956 (Hyatt 1956). In that study, stack concentrations were measured with improved, isokinetic stack sampling systems that were operated alongside the original systems (Hyatt 1955). After six months of sampling, results were compared and correction factors were determined and applied to releases previously reported for 1948-1955. Past that point, the improved sampling system was used.

All values from 1948 through 1975 were adjusted upward further by the LAHDRA team using a sample line loss correction factor equal to 5 for 1945-1958 and 2 for 1959-1975 based on analyses performed by LANL staff (Fuehne 2008). The reduction of the line loss correction factor starting with 1959 is in consideration of the fact that a single stage of high efficiency particulate air (HEPA) filters was added to the combined process exhaust system at DP West in 1959 (Maraman et al. 1975), and the particle size distribution in that exhaust stream likely shifted toward smaller particles. A filter burial correction factor of 2.33 was also applied to plutonium release totals reported by LANL for 1948 through 1975 based on assessments performed by LANL staff (Fuehne 2008). These line loss and filter burial corrections might also be appropriate for years following 1975, but have not been applied in this calculation. No documentation has been found identifying when LANL first applied these correction factors, but routine application is evident by the 1980s.

The maximum effluent concentration used for calculation of priority indices for plutonium releases was 2.0×10^{-14} µCi mL^{-1} from 10CFR20 Appendix B, Table 2. Table 17-1 presents the estimated annual release totals (µCi) and priority indices (dilution volume, L) for plutonium. The priority indices for plutonium over the years of LANL operations range in magnitude from 10^{11} to 10^{18}.

<u>Uranium Effluent Data:</u> The uranium data found range from 1949 to 1996. Some of these data are uranium inventory data from uses in experiments involving explosive testing and some data are from stack monitoring. In the case where a nuclide collection contained both plutonium and uranium, it was counted in the plutonium data. The uranium data are for nuclide collections that contain only uranium. For the explosion data, the mass was multiplied times a specific activity for the nuclide group (for

example, depleted uranium or natural uranium). Uranium data from stack sampling also had the sample line loss and filter burial correction factors applied to all data prior to 1976, in the same manner as described for plutonium releases (Fuehne 2008).

Atmospheric Release Fractions (ARF) and Respirable Factions (RF) (USDOE 1994) were multiplied to get a range of Overall Release Fractions (ORF). The ORF-corrected values represent the amount of the radionuclide that got into the air and contains respirable-size particles. The geometric mean of the ORF, estimated as the square root of the range of values, is 0.001. This value was applied to the entire uranium inventory documented as expended in explosive tests.

The maximum effluent concentration used for calculation of priority indices for uranium releases was 6.0×10^{-14} µCi mL^{-1} for ^{235}U from 10CFR20 Appendix B, Table 2. Table 17-2 presents estimates of annual release quantities and priority indices for uranium. The overall range for the priority indices was from approximately 10^{11} to approximately 10^{17}. In general, in the post-1973 era, the uranium priority indices appear to indicate greater significance than plutonium. In the pre-1973 era, plutonium was of greater significance. It is noteworthy that the years 1967, 1968, and 1969 have very high uranium release values. These values are directly from the LANL documents (see Fig. 17-2 below). During the LAHDRA project it was not possible to confirm if these values were actually quantities released, or whether they might represent quantities expended in explosive testing. It is possible that quantities expended were documented without consideration of fractions that were aerosolized.

TA-15 (R-Site)	1967	Normal Uranium	1.20
TA-15 (R-Site)	1967	Tritium	3.59×10^3
TA-15 (R-Site)	1968	Normal Uranium	0.75
TA-15 (R-Site)	1968	Tritium	4.50×10^3
TA-15 (R-Site)	1969	Normal Uranium	0.75

Fig. 17-2. Unusually high uranium values (in curies) documented by LASL (Andrews ca. 1973)

<u>Tritium:</u> Effluent data obtained for tritium range from 1967 to 1996, even though tritium was used at Los Alamos as far back as 1945 or possibly 1944. No correction factors were applied to tritium data. The maximum effluent concentration used for calculation of priority indices for tritium releases was 1.0×10^{-7} µCi mL^{-1} from 10CFR20 Appendix B, Table 2. Table 17-3 presents estimated annual release quantities and priority indices for tritium. The priority indices for tritium range from 10^{12} to 10^{14}. In the post-1973 era, tritium appears to have been more significant than uranium or plutonium, but less significant than MAP.

Tritium has a relatively short half-life (approximately 12.3 y compared to plutonium and uranium at thousands of years) and it is readily incorporated into compounds. More data are required for pre-1967 tritium releases at LANL. LAHDRA staff have found and added to the project information database additional documents containing tritium release data associated with episodic releases before and after 1967, but these data are scattered across many documents and have not yet been compiled or used to bound releases before 1967.

Radioactive Lanthanum (RaLa): The RaLa testing program at Los Alamos was the subject of a dose reconstruction by LANL personnel, including a source term evaluation (Dummer et al. 1996). All of the RaLa release data obtained by the LAHDRA team are from explosive tests from 1944 to 1962, with no shots conducted during 1951. No correction factors were applied to the activity data by the LAHDRA team. Since it was desired to estimate the actual RaLa releases to air, the same ORF used for uranium (0.001) was applied to RaLa source strength data for each shot.

The maximum effluent concentration used for calculation of priority indices for RaLa releases was 2.0×10^{-9} µCi mL^{-1} for ^{140}La from 10CFR20 Appendix B, Table 2. Table 17-4 presents annual estimates of quantities released and priority indices for the RaLa tests. The priority indices ranged from 10^{11} to 10^{13}. While a detailed evaluation of LANL's dose assessment for RaLa releases has not been performed, it appears from this preliminary assessment that RaLa does not warrant high priority in assessments of airborne radionuclide releases.

Mixed Fission Products (MFP): MFP data reported by LANL begin in 1961 and continue through 1996. Their variability is quite high. The reasons for this variability and the lack of data prior to 1961 have not yet been explored. It is believed that the main source of MFP radionuclides was the Omega reactor. For some years– for example 1969, 1972, 1973, and 1994– the reported MFP activity released was much higher than in other years. The reasons for these elevated values have not yet been explored.

The maximum effluent concentration used for MFP was 1.0×10^{-7} from Footnote 2 to the radionuclide tables in Appendix B to 10CFR20. Table 17-5 presents estimated annual release quantities and priority indices for MPF releases. The priority indices for MFP are not high in relative terms; they range in magnitude from 10^{6} to 10^{12}. If the correction for decay during environmental transport were applied, they would be even lower, since MFP radionuclides in general have short half-lives.

Mixed Activation Products (MAP): MAP make up the largest portion of the airborne radioactive releases after 1973. Reactors and large accelerators are the main producers of MAP radionuclides. At Los Alamos, this would mean the majority of the MAP would come from TA-53 and the Los Alamos Meson Physics Facility (LAMPF), now called the Los Alamos Neutron Science Center (LANSCE). Although

LAMPF started operations in 1971, no pre-1976 effluent data were found for MAP. Based on the conventions used by LANL to report activation product releases, the nuclides included in the MAP "nuclide set" were as follows:

- "MAP",
- Gaseous Mixed Activation Products ("G/MAP"),
- Particulate Various Activation Products ("P/VAP"), and
- Air activation products C-11, N-13, O-15, and Ar-41.

These are all short-lived MAP radionuclides that accelerator Health Physicists traditionally consider to be "MAP." However, this facility also releases activation products that are longer-lived particulates. These particulate releases are traditionally not considered "MAP". Short-lived MAP is measured via an in-stack ion chamber, whereas the particulates are long-lived and measured by counting of in-stack filters in a laboratory.

The maximum effluent concentration used for prioritization of MAP releases was a value of 2.0×10^{-7} µCi mL^{-1} published by the International Atomic Energy Agency (IAEA 1979). Table 17-6 presents estimates of annual release quantities and priority indices for MAP releases. Priority indices varied in magnitude from 10^{8} to 10^{15}. In 1990, the priority index was smaller than in other years. Examination of the available data indicated that for 1991 there are five records with data relevant to the MAP "nuclide set," but for 1990, there are only two records. This paucity of reported data, with possibly some data missing, resulted in the lower priority index for 1990. No further investigation has yet been possible.

Fig. 17-3 presents a combined plot of annual priority index values for airborne radionuclide releases from LANL facilities, and Table 17-7 presents a summary of the classes of radionuclides with highest priority indices for each period of LANL operations.

Table 17-1: Airborne Plutonium Release Estimates and Priority Indices [a]

Year	Release, µCi	Priority Index, L
1948	1.31E+07	6.57E+17
1949	6.36E+07	3.18E+18
1950	4.53E+07	2.27E+18
1951	7.66E+06	3.83E+17
1952	1.23E+07	6.13E+17
1953	6.17E+06	3.09E+17
1954	3.68E+06	1.84E+17
1955	1.45E+07	7.27E+17
1956	9.03E+05	4.51E+16
1957	8.74E+05	4.37E+16
1958	9.68E+05	4.84E+16
1959	2.18E+06	1.09E+17
1960	4.44E+05	2.22E+16
1961	9.50E+04	4.75E+15
1962	1.14E+05	5.70E+15
1963	8.12E+04	4.06E+15
1964	3.36E+04	1.68E+15
1965	1.27E+05	6.35E+15
1966	1.43E+05	7.17E+15
1967	3.75E+05	1.87E+16
1968	3.55E+05	1.77E+16
1969	5.13E+05	2.57E+16
1970	1.49E+05	7.46E+15
1971	7.43E+04	3.71E+15
1972	9.76E+04	4.88E+15
1973	1.01E+05	5.04E+15
1974	9.90E+03	4.95E+14
1975	2.90E+03	1.45E+14
1976	6.79E+01	3.40E+12
1977	1.27E+02	6.35E+12
1978	1.12E+02	5.60E+12
1979	1.09E+03	5.45E+13
1980	7.47E+02	3.74E+13
1981	5.65E+01	2.83E+12
1982	1.12E+02	5.60E+12
1983	1.13E+02	5.65E+12
1984	1.41E+02	7.05E+12
1985	2.13E+02	1.07E+13
1986	2.07E+02	1.04E+13
1987	7.28E+01	3.64E+12
1988	7.23E+01	3.62E+12
1989	4.53E+01	2.27E+12
1990	2.57E+01	1.29E+12
1991	3.55E+01	1.78E+12
1992	1.91E+01	9.55E+11
1993	6.44E+00	3.22E+11
1994	1.25E+01	6.25E+11
1995	8.90E+01	4.45E+12
1996	2.33E+01	1.17E+12

[a] Note regarding scientific notation: $4.96E^{+05}$ equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

Table 17-2: Airborne Uranium Release Estimates and Priority Indices [a]

Year	Release, µCi	Priority Index, L
1948		
1949	1.88E+03	3.13E+13
1950	1.95E+04	3.25E+14
1951	4.54E+03	7.56E+13
1952	4.04E+03	6.74E+13
1953	2.80E+02	4.66E+12
1954	4.61E+03	7.69E+13
1955	6.80E+03	1.13E+14
1956	1.20E+04	1.99E+14
1957	3.67E+03	6.11E+13
1958	3.01E+03	5.01E+13
1959	5.00E+03	8.33E+13
1960	2.52E+03	4.20E+13
1961	2.99E+03	4.98E+13
1962	3.03E+04	5.05E+14
1963	8.88E+04	1.48E+15
1964	1.61E+04	2.69E+14
1965	2.36E+04	3.93E+14
1966	2.38E+04	3.97E+14
1967	2.23E+07	3.72E+17
1968	1.46E+07	2.44E+17
1969	1.50E+07	2.50E+17
1970	2.52E+04	4.20E+14
1971	1.29E+05	2.14E+15
1972	3.66E+04	6.09E+14
1973	1.75E+04	2.92E+14
1974	9.37E+03	1.56E+14
1975	1.07E+04	1.78E+14
1976	1.35E+03	2.24E+13
1977	7.09E+02	1.18E+13
1978	5.27E+02	8.78E+12
1979	9.33E+02	1.55E+13
1980	7.91E+02	1.32E+13
1981	1.27E+03	2.12E+13
1982	1.37E+03	2.29E+13
1983	8.88E+02	1.48E+13
1984	1.21E+03	2.01E+13
1985	7.28E+02	1.21E+13
1986	8.44E+02	1.41E+13
1987	1.08E+03	1.79E+13
1988	5.59E+02	9.31E+12
1989	3.94E+02	6.56E+12
1990	3.49E+03	5.82E+13
1991	7.92E+04	1.32E+15
1992	2.60E+03	4.33E+13
1993	5.09E+03	8.48E+13
1994	3.88E+02	6.47E+12
1995	5.27E+03	8.78E+13
1996	3.90E+01	6.50E+11

[a] Note regarding scientific notation: $4.96E^{+05}$ equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

Table 17-3: Airborne Tritium Release Estimates and Priority Indices [a]

Year	Release, µCi	Priority Index, L
1948		
1949		
1950		
1951		
1952		
1953		
1954		
1955		
1956		
1957		
1958		
1959		
1960		
1961		
1962		
1963		
1964		
1965		
1966		
1967	2.79E+10	2.79E+14
1968	3.17E+10	3.17E+14
1969	3.45E+10	3.45E+14
1970	3.71E+10	3.71E+14
1971	1.02E+10	1.02E+14
1972	6.51E+09	6.51E+13
1973	1.29E+09	1.29E+13
1974	7.32E+09	7.32E+13
1975	6.20E+09	6.20E+13
1976	3.40E+09	3.40E+13
1977	3.86E+10	3.86E+14
1978	1.86E+10	1.86E+14
1979	1.50E+10	1.50E+14
1980	7.52E+09	7.52E+13
1981	7.23E+09	7.23E+13
1982	1.59E+10	1.59E+14
1983	7.89E+09	7.89E+13
1984	1.49E+10	1.49E+14
1985	8.64E+09	8.64E+13
1986	1.07E+10	1.07E+14
1987	3.17E+09	3.17E+13
1988	1.10E+10	1.10E+14
1989	1.44E+10	1.44E+14
1990	1.18E+10	1.18E+14
1991	5.17E+09	5.17E+13
1992	1.30E+09	1.30E+13
1993	1.48E+09	1.48E+13
1994	1.07E+09	1.07E+13
1995	1.11E+09	1.11E+13
1996	5.77E+08	5.77E+12

[a] Note regarding scientific notation: $4.96E^{+05}$ equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

Table 17-4: Airborne RaLa Release Estimates and Priority Indices [a]

Year	Release, µCi	Priority Index, L
1944	1.11E+06	5.55E+11
1945	1.84E+07	9.20E+12
1946	2.06E+07	1.03E+13
1947	2.27E+07	1.14E+13
1948	1.22E+07	6.10E+12
1949	2.83E+07	1.42E+13
1950	1.98E+07	9.90E+12
1951	No shots	No shots
1952	6.37E+06	3.19E+12
1953	1.07E+06	5.35E+11
1954	1.56E+07	7.80E+12
1955	4.08E+07	2.04E+13
1956	3.60E+07	1.80E+13
1957	1.74E+07	8.70E+12
1958	9.85E+06	4.93E+12
1959	8.32E+06	4.16E+12
1960	5.56E+06	2.78E+12
1961	2.43E+07	1.22E+13
1962	1.36E+07	6.80E+12
1963	Testing program completed.	
1964		
1965		
1966		
1967		
1968		
1969		
1970		
1971		
1972		
1973		
1974		
1975		
1976		
1977		
1978		
1979		
1980		
1981		
1982		
1983		
1984		
1985		
1986		
1987		
1988		
1989		
1990		
1991		
1992		

[a] Note regarding scientific notation: $4.96E^{+05}$ equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

Table 17-5: Airborne MFP Release Estimates and Priority Indices [a]

Year	Release, µCi	Priority Index, L
1948		
1949		
1950		
1951		
1952		
1953		
1954		
1955		
1956	9.35E+05	9.35E+09
1957		
1958		
1959		
1960		
1961	1.80E+03	1.80E+07
1962	4.31E+05	4.31E+09
1963	6.77E+05	6.77E+09
1964	3.12E+05	3.12E+09
1965	3.84E+05	3.84E+09
1966	3.98E+04	3.98E+08
1967	1.31E+04	1.31E+08
1968	1.35E+04	1.35E+08
1969	1.44E+08	1.44E+12
1970	1.74E+04	1.74E+08
1971	3.75E+04	3.75E+08
1972	7.13E+08	7.13E+12
1973	2.10E+08	2.10E+12
1974	6.11E+03	6.11E+07
1975	2.31E+03	2.31E+07
1976	1.97E+03	1.97E+07
1977	2.85E+03	2.85E+07
1978	1.69E+03	1.69E+07
1979	1.71E+03	1.71E+07
1980	2.29E+03	2.29E+07
1981	1.61E+03	1.61E+07
1982	1.97E+03	1.97E+07
1983	9.26E+02	9.26E+06
1984	1.69E+03	1.69E+07
1985	1.40E+03	1.40E+07
1986	2.64E+03	2.64E+07
1987	1.29E+03	1.29E+07
1988	1.16E+03	1.16E+07
1989	4.36E+05	4.36E+09
1990	2.01E+04	2.01E+08
1991	4.70E+03	4.70E+07
1992	1.29E+04	1.29E+08
1993	3.28E+03	3.28E+07
1994	3.00E+08	3.00E+12
1995	1.14E+03	1.14E+07
1996	4.07E+02	4.07E+06

[a] Note regarding scientific notation: $4.96E^{+05}$ equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

Table 17-6: Airborne MAP Release Estimates and Priority Indices [a]

Year	Release, µCi	Priority Index, L
1948		
1949		
1950		
1951		
1952		
1953		
1954		
1955		
1956		
1957		
1958		
1959		
1960		
1961		
1962		
1963		
1964		
1965		
1966		
1967		
1968		
1969		
1970		
1971		
1972		
1973		
1974		
1975		
1976	5.89E+09	2.95E+13
1977	4.77E+10	2.39E+14
1978	1.17E+11	5.85E+14
1979	1.19E+11	5.95E+14
1980	1.46E+11	7.30E+14
1981	3.53E+11	1.77E+15
1982	2.51E+11	1.26E+15
1983	4.64E+11	2.32E+15
1984	7.37E+11	3.69E+15
1985	1.26E+11	6.30E+14
1986	1.12E+11	5.60E+14
1987	1.50E+11	7.50E+14
1988	1.21E+11	6.05E+14
1989	1.56E+11	7.80E+14
1990	1.13E+05	5.65E+08
1991	5.72E+10	2.86E+14
1992	1.43E+11	7.15E+14
1993	3.34E+10	1.67E+14
1994	1.01E+11	5.05E+14
1995	4.34E+10	2.17E+14
1996	1.12E+10	5.60E+13

[a] Note regarding scientific notation: $4.96E^{+05}$ equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

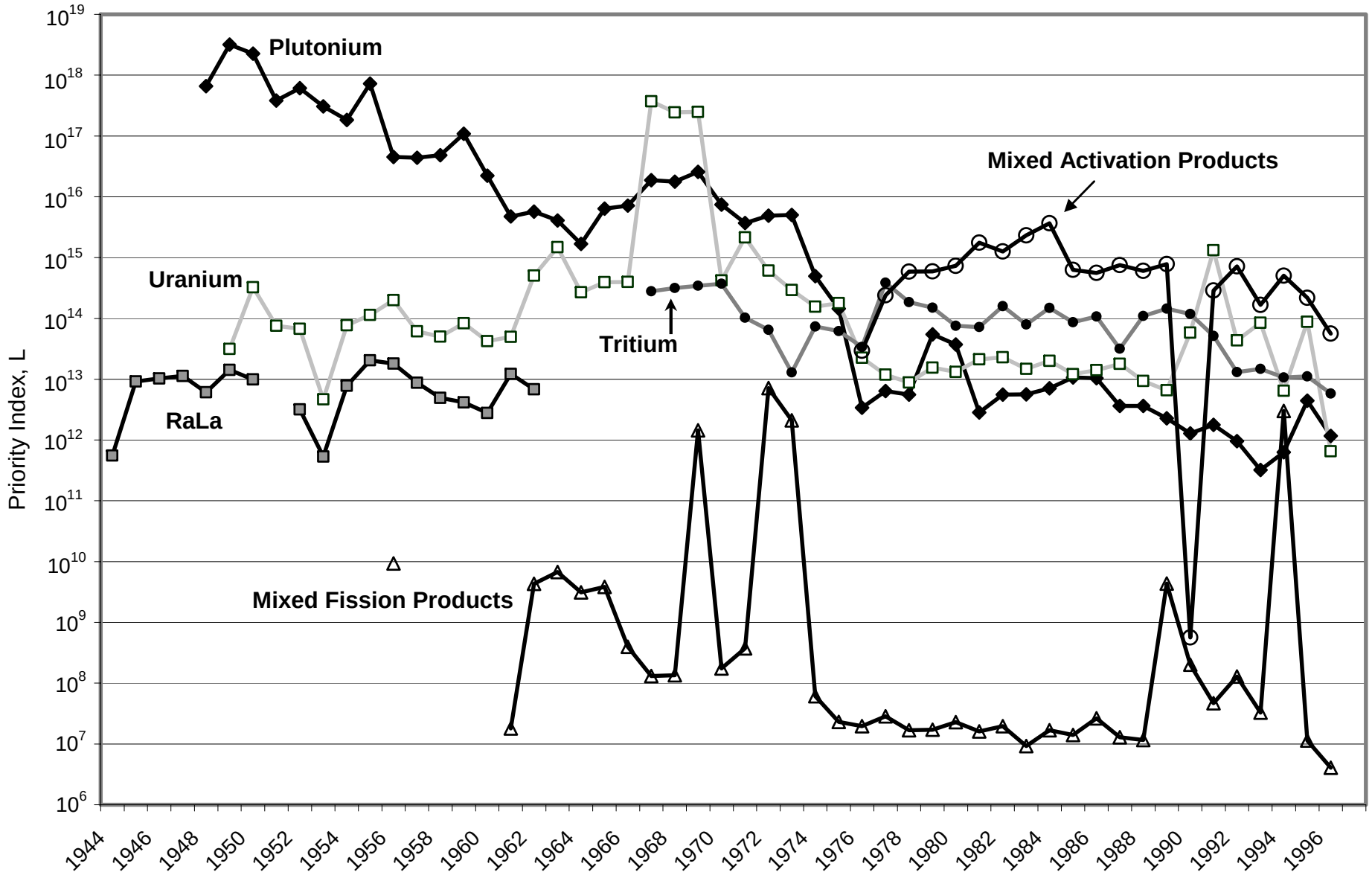

Figure 17-3. Priority Indices for Airborne Radionuclide Releases from LANL Operations

Table 17-7. Classes of airborne radionuclides with highest priority indices for each period of LANL operations

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

Conclusions regarding prioritization of airborne radionuclides

The LAHDRA prioritization of airborne radionuclide releases shows that, based on LANL compilations of releases, plutonium and uranium were of primary concern until the early 1980s. From then until the present, MAP radionuclides appear to have been of primary concern. However, in some cases, limited or no data were found in LANL compilations of releases for important nuclides such as plutonium (D Building data and pre-1948 data), polonium, tritium before 1967, all nuclides pre-1950, and non-point source emissions.

A calculation was completed in October 2006 that analyzed the reported releases from DP West for calendar year 1957, using the actual daily stack sampling and analysis reports. This was done to compare with the LANL compilation (Andrews ca. 1973) that has been the basis for asserted releases of plutonium from LANL. The analysis of the 1957 data by the LAHDRA team showed that 40% of all operating hours at DP West Site were not monitored, with the unmonitored periods mostly associated with weekends and holidays. Therefore, a method for estimating the hours where the stacks were not monitored is needed. The method used by LANL was likely conservative, in that it scaled from operating hours to estimate hours in which no stack measurement was made. The LAHDRA review of the 1957 data also showed that the simple assumptions made in the early 1970s, such as stack and sample stream flow rates, were used for all periods. These assumptions appear to have not always been appropriate. The air concentration and fallout tray data for the 37-d operating period during 1957 over which the Jordan and Black work was performed (Jordan and Black 1958) could be used to benchmark air transport models for assessment of airborne releases from DP West Site. However, the LAHDRA project team has been unable to identify the 37-d period, and LANL staff have been unable to supply information about the Jordan and Black study beyond what is contained in the associated journal paper.

Comments and Issues

Data completeness - This prioritization effort was intended to present a "first look" at the scope and extent of radionuclides released at LANL over the years of its operation. Because the primary focus of LAHDRA was information gathering, limited effort was expended toward entering or evaluating raw data identified in historical documents at LANL. In general, the values used in the prioritization came from LANL compilations, with adjustments made as available data supported. Little effort was expended to analyze the data from logbooks or other more detailed data sources. A significant amount of original release information (that is, lab measurements of a filter from a stack) for the 1950s and 1960s is available, and could be captured and analyzed if further evaluation of airborne releases is undertaken.

Polonium - No effluent data have been found for polonium, other than gross alpha measurements of buildings and stacks at DP East Site, where polonium and other materials were handled and processed. It is known that significant quantities of polonium were used. Due to its shorter half-life, perhaps thousands of times more curies of polonium then plutonium were used. In the early years, plutonium was the most valuable substance on earth and was held in strict control. However, since polonium was more readily available, it was not inventoried as closely as plutonium. Large amounts were used in explosive or destructive tests for nuclear weapon initiators.

An annex to B Building was built by the end of March, 1944. It held a 20-mm, remotely fired, anti-aircraft autocannon used for testing scaled-down versions of gun weapon components and gun initiators. Operational in April 1944, it had performed nearly 180 experiments by the end of September (about one per day) with unknown quantities of polonium and beryllium released (LASL 1944-1945). In August 1944, a "coffin" was authorized, that is a box operated at negative pressure with a gas mask filtered exhaust, to be used to limit contamination of the machine gun and room during experiments with plutonium. It was to be placed into operation in September, 1944. While the LAHDRA team has addressed releases of beryllium from the B-Building gun testing (See Chapter 20), polonium releases from that activity have not yet been addressed.

Pre-1967 tritium - There are no pre-1967 effluent data for tritium. The LAHDRA project has identified documents that refer to significant tritium releases before 1967, in most cases associated with accidental or episodic releases. This information is scattered across many historical documents, such as incident reports. The LAHDRA team has identified no location in which documents related to tritium releases before 1967 have been assembled. If time could be devoted to a directed search of records (some already captured by the LAHDRA team and some not) for episodic tritium release data, it is likely that a tritium source term for years before 1967 could be bounded.

Unmonitored releases - In the early years of Los Alamos operations, some plutonium processing facilities such as D Building and the facilities at the DP West Site, were designed and operated with positive building pressure (LASL 1947) (see Fig. 17-4 below). This could have resulted in significant unintentional release of building air out of doors and exit points other than the stacks. Similar release pathways could also be active for large facilities such as LANSCE.

> The ventilation system has been designed so as to give a change of air in each of the operating areas once every two minutes. This has been sufficient to keep the plutonium concentration in the rooms well below tolerance. Outside air is blown into each of the buildings through cloth filters at such a rate as to maintain the inside pressure slightly above atmospheric. It is then drawn out through the central duct system to the air filtration plant, where it passes through a bank of five electrostatic precipitators and then is exhausted up the stacks. The system handles 200,000 cubic feet of air per minute. The average

Fig. 17-4. Excerpt from a description of DP Site facilities and their ventilation systems (LASL 1947).

Small contributors - There are a number of nuclides like Mn-54, Au-194, or Ac-227, which do not fall into one of the six existing "nuclide sets". Since there were few data records involving these radionuclides, and it is known that these nuclides were not primary radionuclides that LANL was working with, priority indices were not calculated. The overall contribution of these nuclides is thought to be very small and subsequently no priority indices are computed or assigned in this calculation.

Beryllium - In the site-wide FEIS (USDOE 1979), Table 4.1.2-8 contains information on explosive tests for uranium and beryllium (see Fig. 17-5 below). Using this information, the priority indices in Table 17-8 were computed based on required dilution volume in liters. Note that the priority index for beryllium is five times that of uranium. Furthermore, these data are only from explosive tests, and as discussed in Chapters 11 and 20, there were other sources of beryllium such as the beryllium shop and initiator testing.

ORF Corrections – In the site-wide FEIS (USDOE 1979), the percentages of various elements aerosolized from explosive tests are listed as 10%, or 0.1 (see Fig. 17-5). In this LAHDRA prioritization calculation, it was asserted that the Overall Release Fraction (ORF) was 0.001. This was based on a combination of Airborne Release Fraction and Respirable Fraction. If the LANL asserted figure of 0.1 were to be used, the uranium priority index would change significantly for the years in which uranium was used in explosive tests. For the LAHDRA prioritization, the ORF value of 0.001 was retained as it was judged to be more appropriate.

TABLE 4.1.2-8

CALCULATED ATMOSPHERIC CONCENTRATIONS OF ELEMENTS USED IN DYNAMIC EXPERIMENTS[c]

Element	1976 Annual Usage (kg)	Percent Aerosolized	Annual Avg. Conc. (ng/m^3) @ 4 km	Annual Avg. Conc. (ng/m^3) @ 8 km	Applicable Standard (ng/m^3)
Uranium (D-38)	1023	10[a]	0.1	0.04	9000
Be	25.5	2[a]	0.0007	0.0002	10 (30 day avg.)
Hg	36.1	100[b]	0.05	0.02	None
Pb	18.6	100[b]	0.02	0.08	None
TOTAL			0.17	0.068	10,000 (For total heavy metals N > 21)

a)Based on experimental measurement.

b)Assumed percentage aerosolized.

c)See Appendix H, pages H-37, H-38, and H-104, for update.

Fig. 17-5. 1979 FEIS Data on Uranium and Beryllium in Dynamic Experiments

Table 17-8. Priority index calculations for depleted uranium and beryllium emissions in 1976 based on data from LANL's 1979 FEIS

Material	1976 Annual Usage (kg)	Percent Aerosolized	Aerosolized Quantity (kg)	Applicable Standard (ng/m^3)	Priority Index (L)
Depleted Uranium	1023	10%	102.3	9,000	1.14×10^{13}
Beryllium	25.5	2%	0.51	10	5.10×10^{13}

Pre-1973 LANL plutonium releases – Figs. 19-6 and 19-7 are a table and text, respectively, from the site-wide FEIS that document the 1.2-curie cumulative historical release value for airborne plutonium through 1972. The assessment of airborne plutonium releases from LANL operations would benefit from further examination of airborne plutonium releases before 1948, as there were minimal control measures in place during this period.

TABLE 4.1.2-3

ATMOSPHERIC RELEASES OF RADIOACTIVITY

Cumulative Radionuclides Released to the Atmosphere Prior to 1973[a]

^{3}H	120,000
Mixed Fission Products	0.006
^{235}U	0.086
^{238}U	0.005
^{238}Pu	0.056
^{239}Pu	1.2

Fig. 17-6. Cumulative airborne radionuclide releases through 1972 as reported in the LANL FEIS

The inventory of radioactive atmospheric releases before 1973 (see Table 4.1.2-3) was made on the basis of stack sampling through December 1972.[4-42] The absence of stack sampling programs during the early years of the Laboratory and continuing uncontained tests with high explosives involving natural or depleted uranium prevented preparation of a complete inventory. In general, the inventory covers releases during the period from 1948 through 1972 for plutonium, 1961 through 1972 for mixed fission products, and 1967 through 1972 for other radionuclides such as tritium, ^{235}U, and ^{238}U. Inventories of short-lived nuclides such as ^{131}I, ^{88}Rb, ^{133}Xe, ^{135}Xe, ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O (whose half-lives range from about 2 minutes to 8 days) were not included, since they decay rapidly and have little biological significance. The activity values for ^{239}Pu include contributions from ^{241}Am and other alpha emitters associated with the ^{239}Pu. Data since 1973 is based on actual stack sampling.

Probable releases of radioactivity to the atmosphere during the next 25 years are likely to be less than releases to date. For example, if releases of plutonium were to continue at the 1976 rate for 25 years, the cumulative amount would be less than 1.5% of the total plutonium released before 1976. Construction and use of a new plutonium facility with extensive filtration equipment is expected to significantly reduce plutonium emissions. At the 1976 rate, tritium releases over 25 years would be about the same as the total before 1976. New treatment equipment and construction of new facilities for tritium research are expected to significantly reduce tritium releases from the 1976 level.

Fig. 17-7. Text regarding airborne releases before 1973 from the LANL FEIS

ORF Corrections – In the site-wide FEIS (USDOE 1979), the percentages of various elements aerosolized from explosive tests are listed as 10%, or 0.1 (see Fig. 17-5). In this LAHDRA prioritization calculation, it was asserted that the Overall Release Fraction (ORF) was 0.001. This was based on a combination of Airborne Release Fraction and Respirable Fraction. If the LANL asserted figure of 0.1 were to be used, the uranium priority index would change significantly for the years in which uranium was used in explosive tests. For the LAHDRA prioritization, the ORF value of 0.001 was retained as it was judged to be more appropriate.

Alternate Methods for Characterizing Airborne Releases–

Measurements of Plutonium in Soil as Indicators of Historical Releases

Until around 1978, releases of airborne plutonium from LANL were either not measured at all or were improperly measured or reported. Major release points that were not measured for plutonium include the historic D Building, the first plutonium component manufacturing facility in the world, and DP West Site releases before 1948. D Building operated until around 1953. Also never considered in LANL compilations of plutonium releases were non-point source emissions from major fires at plutonium disposal areas in the 1940s and radioactive disposal area operations that continue to this day. Until the around 1959, release points such as DP West at LANL were not provided with single stage HEPA filters (Maraman et al. 1975). A second stage of HEPA filters were finally installed around 1973. Until the mid-1950s, the DP West Site Stacks were not equipped with an appropriate sampling system, resulting in underreporting of releases by large factors. Thus, the LAHDRA project had a need to estimate potential releases from LANL operations using methods beyond those based on reported stack monitoring results. One method identified was to use amounts of plutonium measures in soil samples collected around Los Alamos to estimate the amount of airborne plutonium that was released.

Efforts by LANL

The staff at LANL attempted to measure the amount of plutonium in the soils around LANL in the 1957-1958 timeframe. Fig. 17-8 is taken from the 1958 publication "Evaluation of the Air Pollution Problem Resulting from Discharge of a Radioactive Effluent" by Harry Jordan and Ralph Black (Jordan and Black 1958). The darker areas in the figure indicate the canyons. The image shows circles of increasing distance from the main stacks at D. P. West along with soil sampling results and locations. The authors asserted that they were able to compare their values with the actual release data since releases were measured at D. P. West. Only the 6 results to the east (right) that are circled were used by Jordan and Black because they "show rather remarkable agreement" with the LANL stack effluent records showing 13.1 g or 0.82 Ci of plutonium (as stated in their own words). Results that were substantially higher were not used because they thought that they were higher because of failure of "attempts to avoid extraneous contamination." Although they asserted agreement, they were apparently unaware of or ignored major changes in the stack sampling system in 1955 that were the subject of a study by Edwin Hyatt that resulted in significant modification of release estimates.

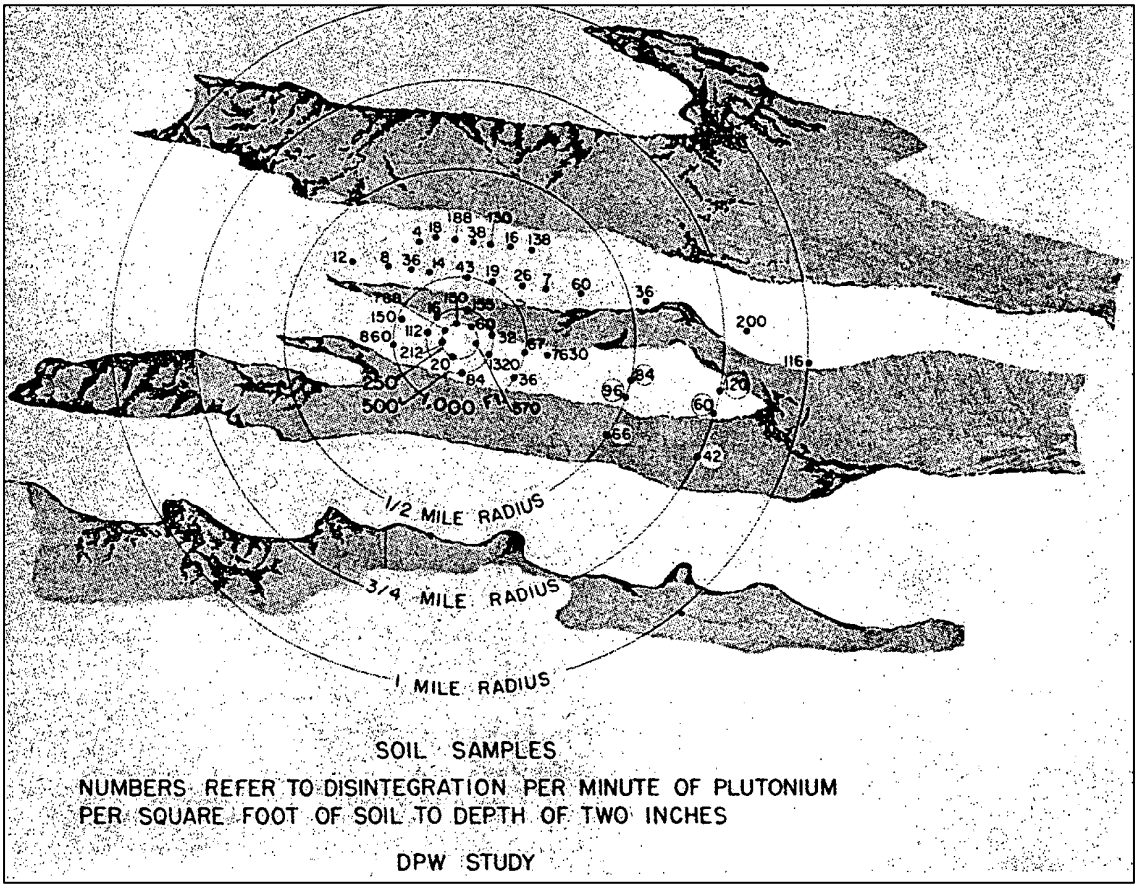

Fig. 17-8. Measurements of Plutonium in Soil at DP West Site as reported by Jordan and Black

The LAHDRA team sees at least five major problems with the Jordan and Black paper:

1. LAHDRA is unable to find any supporting records or logbooks about the referenced work.
2. Jordan and Black excluded any high samples, for what appear to have been erroneous reasons.
3. Jordan and Black compared the soil to incorrect stack monitoring results and asserted that the soils and stack data agreed. The DP West stack measurements are now thought to be up to a factor of 100 or more in error (lower than the correct value), even without inclusion of pre-1948 releases at DP West or any other LANL source terms. Edwin Hyatt replaced the stack sampling system in 1955 and found that the old system under-sampled the releases by a factor of approximately 20 as compared to the 1955 sampler (Hyatt 1955, Hyatt 1956). In addition, corrections for sample line loss of up to 5 and filter burial of 2.33 were not generally made until the late 1970s (Fuehne 2008).
4. The lab at LANL analyzed too much soil at once, resulting in low and variable recovery of the plutonium from soil in the acid leaching process.

5. The radiochemist responsible for the soil analysis has stated his results were only intended to be qualitative (whether plutonium is present) and not meant to be quantitative (how much plutonium is present) (Flack et al. 2004).

In 1971, other Los Alamos scientists attempted to reproduce the work of Jordan and Black. W. Purtymun and W. Kennedy published "Plutonium and Strontium in Soil near Technical Area 21"(Kennedy and Purtymun 1971). Their measured soil concentrations were much higher than Jordan and Black's. In order to explain the higher soil concentration, the 1971 report attempted to correct for the small amount of global fallout from nuclear weapons testing and also assumed four times more plutonium was deposited on the soil from the releases. By assuming four times more plutonium was deposited, Kennedy and Purtymun also asserted that their results agreed with invalid and significantly understated stack measurements. The LAHDRA team took steps in their evaluation to avoid the problems with the Jordan and Black analysis that are identified above.

Efforts by the LAHDRA Project Team

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

Initial Assessment

The initial iteration of an assessment by LAHDRA to estimate airborne plutonium releases was based on 37 measurements of plutonium in soil samples collected near Los Alamos from 1975 to 1977 (Purtymun et al. 1980). These measured concentrations of ^{239}Pu in soil included global fallout from atmospheric testing of nuclear devices. The average concentration of ^{239}Pu of distant sample sites (approximately 50 miles from LANL) was 0.006 ± 0.001 pCi g^{-1}. This value was subtracted from the 37 values used in the analysis. The "corrected" soil concentrations reflected 0.003 to 0.045 pCi g^{-1} net positive contributions of ^{239}Pu from LANL operations. None of these measurements were near the release points.

The Radiological Safety Analysis Computer program was run with Los Alamos meteorological data to calculate ^{239}Pu deposition at various distances in each direction from a unit release (1 Ci) of ^{239}Pu over 50 y (Schrader 2003). Pasquill-Gifford Stability Class C and a deposition velocity of 0.001 m s^{-1} were assumed. The calculated deposition at each distance was converted to a soil concentration based on the annular area involved and the soil density and sampling depth reported by LANL. The ratio of each

measured soil concentration to the concentration calculated for that same area from the RSAC modeling of a unit release yielded a factor that corrects the unit source in RSAC to give agreement between the soil data and the RSAC results. For example, a ratio of 15 would indicate that 15 curies of plutonium was released rather than 1 Ci.

The ratios over the 37 sampling locations were log-normally distributed. Based on the distances involved with releases from D Building (where plutonium was first processed), the geometric mean was 620 curies, with a factor of uncertainty (geometric standard deviation of the mean) of 1.2. For the distances associated with releases from the DP Site (where plutonium processing took place from late 1945 to 1978) the geometric mean was 670 curies, with a factor of uncertainty of 1.3. While these results have a high degree of mathematical uncertainty, they indicated that airborne plutonium releases from LANL operations could have been hundreds of times higher than the 1.2 Ci officially reported, and were much closer to the actual LANL releases.

Second Iteration

Following the initial analyses based on a small sample size, a search for additional soil sampling data was performed, and over 600 soil sample analyses were located (Fresquez et al. 1996). A new analysis was done using this expanded dataset. The ratio of plutonium and cesium was calculated using LANL data and plotted along with the dry pCi g^{-1} of plutonium and cesium. Further examination of the resulting data plotted as a lognormal cumulative frequency distribution reveals that there are two datasets for plutonium:

- Those measurements that reflect contributions from LANL operations ("impacted" measurements), and
- Those measurements that reflect no significant contribution from LANL operations, only fallout from weapons testing ("fallout" measurements).

A mean value for fallout from LANL publications that was consistent with the dataset for fallout was subtracted from the plutonium to get net plutonium for the "impacted" samples. The values of these impacted samples were then plotted on a map at the associated sample collection location.

Two approaches were then used. First, 679 soil samples at 34 sample points were analyzed. Of these, 106 samples at 24 sample points were judged impacted based on analysis of the plot of plutonium-to-cesium ratios. These points were used for geospatial studies of the location and magnitude of elevated levels of plutonium soil concentration. This first approach was oriented towards analysis of the data, not towards estimation of LANL releases. The ^{239}Pu to ^{137}Cs ratio is the middle curve in Fig. 17-9. As can be seen, the ratio sharpens the differences observed in ^{239}Pu, with a slightly worse fit to a lognormal distribution. This ratio helps establish the point at which samples impacted by LANL operations can be

detected. A ratio of about 0.065 marks the break (or "knee") in the line, above which data shows evidence of LANL impact, and below which, the site added ^{239}Pu is so low that the variability of fallout ^{239}Pu and ^{137}Cs masks its presence. This shows that the population of a large number of soil measurements can be used to separate the LANL-impacted locations from those that exhibit fallout alone. The higher one restricts the data above the ratio of 0.065, the less influence fallout has on the ^{239}Pu concentration.

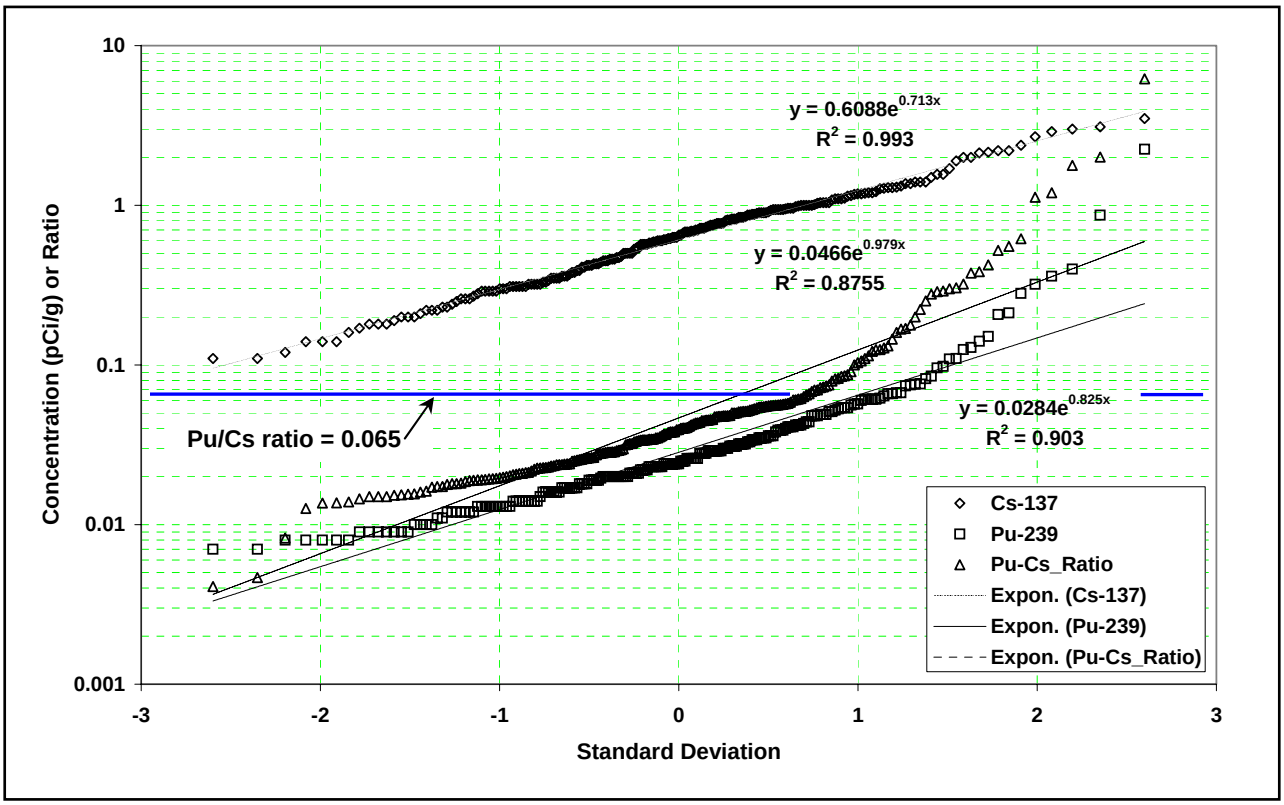

Fig. 17-9. Cumulative Frequency Distributions of ^{137}Cs, ^{239}Pu, and Pu/Cs Ratio Data

In the second approach, a total uncertainty for each soil sample was calculated, and only those measurements with uncertainty in the plutonium to cesium ratio less than 25% were analyzed. This resulted in a data set with 119 members. The plutonium-to-cesium ratio was studied, and the Pu/Cs ratio <0.065 criterion was used to select a 37-sample subset of the 119 samples previously selected for low uncertainty. These samples lie within 5.5 km of either DP West Site or D Building. The results from use of these 37 samples were less dependent on the assumed background from fallout, since the values for plutonium were higher and the background is a smaller percentage of the value.

For these 37 samples, the net plutonium and the range and bearing from the D Building and DP West Site were calculated. The RSAC program was used to calculate the soil concentration as a function of wind

direction and distance for a one-curie source term. When divided into the net sample data, an estimate of the integrated LANL source term was obtained for each of the 37 samples.

The cumulative frequency distribution plots for all 37 sample points for either DP West Site as source or D Building as source are shown in Fig. 17-10. The results were log-normally distributed. If the release was attributed to the DP Site, an average of 60 Ci and a median of 12 Ci were obtained with a geometric standard deviation (factor of uncertainty) of 9. If the site releases were attributed solely to D Building, an average of 101 Ci and a median of 46 Ci were obtained with a corresponding geometric standard deviation (factor of uncertainty) of 5. The smaller uncertainty for D Building suggests that large and previously undocumented releases from D Building could have occurred. However, these results rely on many parameters, which should be the subject of further study. The methods established with this analysis, when validated, could be extended to other contaminants of concern for which monitoring data are not available for key periods of time, such as beryllium.

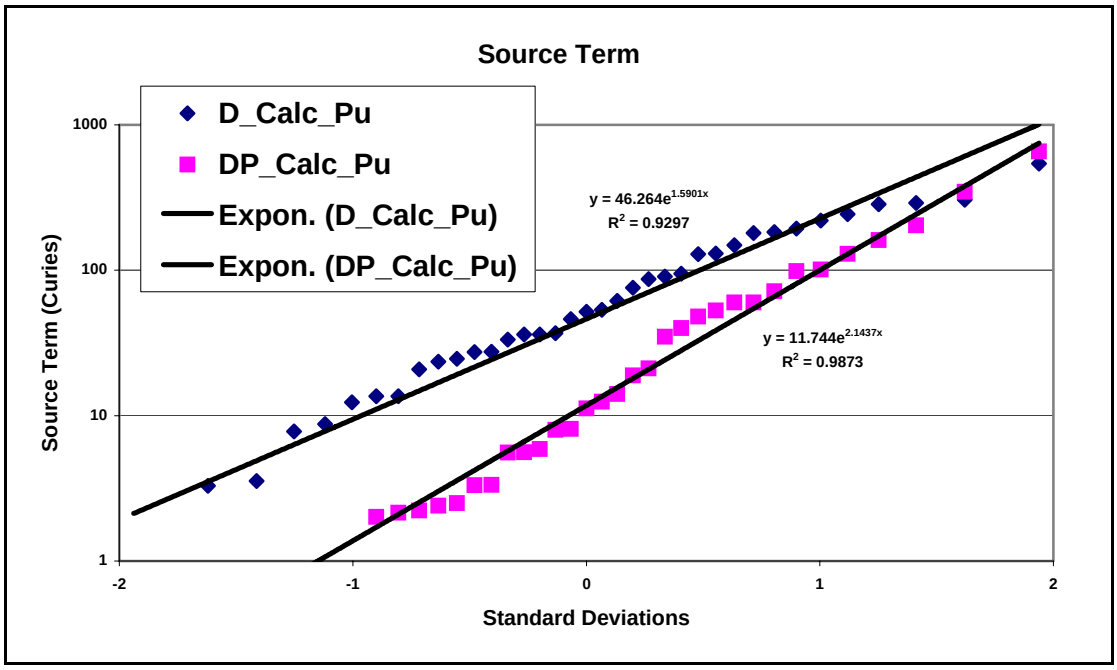

Fig. 17-10. D-Building and DP West Site Source Term Fits

Finally, an attempt was made to explore the relative contribution of D Building and DP West Site to estimated site-total releases. Many combinations of the possible release totals for the two sites were analyzed to find the breakdown that best satisfied the following criteria:

- Minimize the absolute value of the difference between concentrations calculated from LANL releases (D Building plus DP West Site) and measured soil concentrations, averaged over all measurement locations
- Minimize the standard deviation of that mean (i.e., minimize uncertainty).

If one sums a fraction of D Building results with that of DP West Site adjusted for 100% release, the curve would lie midway between those shown in Fig. 17-10. The slope progressively decreases from a factor of 9 (100% DP West Site) to a factor of 5 (100% D Building). A completely flat curve would show that all of the measured soil samples provide the same result, indicating no uncertainties in the answer. Thus, although DP Site happens to fit a lognormal distribution better than D Building, the results suggest most of the releases came from D Building.

Additional Refinements– Jordan and Black Revisited

A detailed review of the 1958 Jordan and Black journal paper was performed during 2006. The soil data used by Jordan and Black have orders of magnitude variability. When plotted as a function of downwind distance, no radial dependence is observed. The air concentration data and fallout tray data are not correlated. The issues with these data lead Jordan and Black to select only six data points as representative, rejecting 85% of their own data. Using the same six points selected as representative by Jordan and Black, the LAHDRA team was unable to reproduce the asserted release, indicating other undocumented assumptions may have been used. The asserted release is consistent with the 1973 "Joe Graf binders" compilation assembled by LANL for the first site-wide environmental impact statement. The deficiencies in that estimate include a lack of pre-1948 data, an estimate for DP West alone for 1948-1950, absence of sample line loss and burial correction factors, no releases from non-point sources such as dumps and dump fires, and no releases from D Building. In summary, the Jordan and Black data lack a basis and any supporting information that would permit its use for back-calculation of the plutonium source term in air.

Material Disposal Area G Calculation

A calculation was completed by the LAHDRA team in November 2006 for non-point source emissions from Material Disposal Area (MDA) G. A LANL staff member had objected to use of soil data from that area for estimating DP West emissions (Shonka and Mejias 2006). This assessment addresses whether soil samples were impacted by MDA G operations, resulting in a falsely high assertion of source term from either DP West Site or D Building. The LAHDRA calculation demonstrated that the LANL

assertion was correct, and that soil samples in that area are significantly impacted by operations at MDA G. However, this calculation also indicated that the release of plutonium from MDA G may be the most important source of plutonium released by LANL since 1981. This non-point source emission has not previously been considered or reported by LANL. The data from one particular location show a gradual reduction of soil concentrations over time, which has been reported by LANL elsewhere. This reduction implies that back-calculation of source terms from the 1940s could be low for data collected in the late 1970s and late 1980s if weathering is not considered.

Identification of Another Potential Dataset for Sampling of Soils Near D Building

While reviewing the ERSS Domino database in March 2007, a LAHDRA document analyst noticed an urgent request in 1993 by LANL staff for soil sampling from the hillside of Los Alamos Canyon, near the location of the former Original Technical Area, to support an EPA audit. In response to a request by the LAHDRA team, Dave Sarracino from the LANL sample office searched his database and provided a printout of sample results associated with that documented request from that ERID (LANL 1993b).

An e-mail authored by LANL staff member M. McNaughton was added that explained that the sample area, depth, and volume were not available because those data were considered not relevant. McNaughton went on to opine that the data should not be used for source term calculations since he felt the locations were impacted by water runoff from TA-1.

The data provided by LANL fit a single log-normal distribution (97%) with a median value of 11 pCi g^{-1} and a geometric standard deviation of 3.3. This indicates that 95% of the data lie within a factor of ten of the median of 11 pCi g^{-1}. The previous environmental monitoring data LAHDRA used for source term calculations had plutonium levels greater than background (background samples were not averaged in) and had a geometric mean that is significantly less (by more than two orders of magnitude) than these hillside samples. Because of the closer distance, these results support median release estimates of between 1 and 100 Ci, with no correction for weathering.

Arguments for and against the use of these samples can be summarized as follows. Some LANL staff members' opinions as to why the 1993 hillside/bench top samples should not be used were summarized in a 23 October 2007 e-mail from McNaughton that asserts that sampling locations in the 1993 campaign were selected to correspond to locations of the effluent pipes known as outfalls numbered 137; 138, and 140 along with locations down-gradient from these pipes. It goes on to assert that almost all plutonium at these locations was therefore carried by water and thus the data were unsuitable for use in characterizing airborne releases from D Building. LAHDRA team members believe that the 1993 hillside/bench top samples are worthy of evaluation because, aside from McNaughton's assertions, there is no evidence that

the statements in his e-mail reflect the actual case. The referenced McNaughton e-mail was provided without references.

The planned sampling sites appear to follow straight lines and show no meander of a typical gravity flow path on irregular terrain. The TA-1 area was documented to have been covered with many feet of clean fill following the removal of D Building. This removed the washout source term for up to 40 y (1953 – 1993). Any water flow over the hillside over the last 40 years would have tended to remove plutonium previously deposited along water flow pathways, not add to it. If there is a new or continuing source term from TA-1 as McNaughton suggests, LANL would need to remediate or mitigate it.

The bench top is not a manmade structure, such as a weir, that would have uniform flow over the entire area. Surface water under gravity flows along low lying channels. In rocky terrain such as the bench top, the flow channels do not change over time as much as in alluvial plains, where episodic floods can change the path of a stream. The flow behavior has been observed in that area during rainfall by LAHDRA team members. The materials deposited in those channels tend to be variable over the years with gradual buildups of sedimentary deposits followed by scouring during episodic high flow periods. Thus, waterborne material deposited during the first ten years of TA-1 operations would likely no longer be present in 1993 in the water pathways. If the samples along water flow paths simply integrated, as McNaughton's argument implies, then the streams in the bottom of the canyons would be highly hazardous locations.

Thirty nine of the sampling locations (43%) in the 1993 sampling were assigned (one of eight) identical values, likely because there was insufficient material at each location to make a sample, and collected soil was composited and analysis yielded a single value. Several of the sampling locations (3) were sampled to depths of over a foot. The soil concentrations at those sites are similar to others in the data set. These locations were likely not along water flow paths.

The data are well correlated (97%) with a single log-normal distribution, with a median of 11 pCi g^{-1} and a geometric standard deviation of 3.3. If there were two processes at work (areas with or without water pathway transport mechanisms), there would likely have been more than one distribution evident.

The data should be examined for potential utility in characterizing historical releases because of the paucity of data regarding D Building releases, which were not measured by LANL. The data could provide another "piece of the puzzle" for estimating D-Building releases.

Suggestions for Improvement of the Current Analysis

The quantity of plutonium released by LANL appears to have been potentially one hundred times or more higher than LANL has asserted. However, the historical LANL soil measurements data that are available and have been used to date for back calculation of the LANL plutonium source term are not ideally suited for this task. Attempts by the LAHDRA team to use existing soil analyses have been critiqued by a LANL staff member citing several issues– some acknowledged by the LAHDRA team and some disputed. Unless LANL has additional documentation that could clarify this issue, a new program of soil sampling, oriented towards resolving the magnitude of releases from significant operations, would be desirable.

The areas around D Building and DP West have been heavily disturbed and suitable soil sampling locations would be problematic. A LANL Technician observed that the hillside of South Mesa across Los Alamos Canyon from the TA-1 has remained relatively undisturbed. This area should be considered for a new program of soil sampling. The samples should continue along the canyon rim from the bridge at Diamond Drive to the area across from D.P. West. If possible, the samples should be analyzed with a new method of measurement called Inductively Coupled Plasma Mass Spectrometry (ICP-MS). This method can distinguish between weapons-grade plutonium samples that have not been used in a nuclear weapon and fallout samples with plutonium left over after a nuclear detonation. The United States Transuranium and Uranium Registries (USTUR) have performed an initial study of the method with promising results. This method and new analysis of the samples might permit accurately estimating how much of the plutonium found in any individual living in Los Alamos was due to global fallout and how much was due to releases of plutonium from LANL.

Without any new soil samples, the material found by LAHDRA in various LANL document repositories could be used for source term estimation, with a more rigorous effort to quantify uncertainties associated with various parameters.

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

Before the late 1970s, plutonium releases from Los Alamos operations were either not measured or were inaccurately measured and reported by LANL. Consequently, alternate methods are needed for determining airborne releases from the early operations at LANL that could have affected off-site populations. The LAHDRA project team investigated the use of data concerning the plutonium levels in tissues obtained from autopsies of LANL residents to estimate plutonium releases.

The LANL Human Tissue Sampling Program

The Human Tissue Analysis Program was a 35-year effort by LANL to study the levels of plutonium in workers and in the general population of the United States. The general population was exposed to plutonium from atmospheric testing of nuclear weapons. Populations located near plutonium facilities, such as the D Building and DP West Site in Los Alamos, were also exposed to plutonium released during operations. Fig. 17-11 is an autoradiograph of a lymph node taken from the lung of a deceased worker from Los Alamos (McInroy 1995). It shows several groups of alpha tracks (radiating in a typical star pattern) from tiny particles of plutonium inhaled while working at the laboratory.

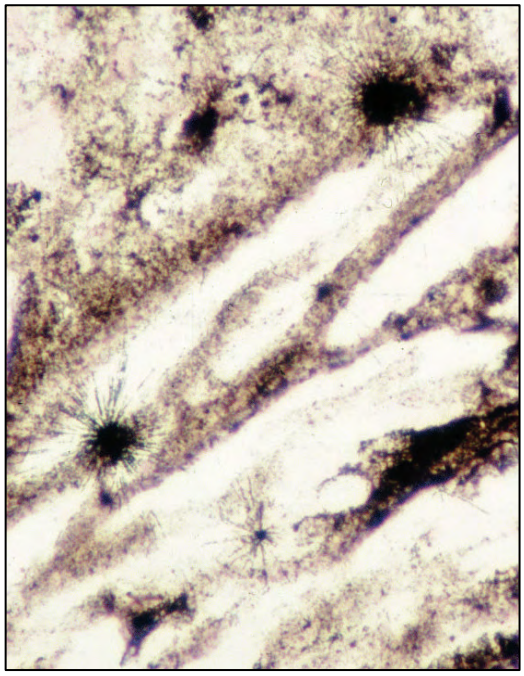

Fig. 17-11. Alpha tracks from plutonium in former worker's lung tissue

Compilations of the LANL human tissue analysis data have been published periodically, and the Los Alamos Science magazine summarized the program in the November 23, 1995 issue that was devoted to a discussion of the Human Radiation Experiments (McInroy 1995). Researchers at LANL first began obtaining samples of tissues from autopsies performed in Los Alamos at the medical center following a nuclear criticality accident that resulted in the death of Cecil Kelley in 1959. He had worked at LANL for many years and had plutonium in his body before the accident. The collection and analysis of tissues was intended to answer questions about the behavior of plutonium in the human body. In later years, the program was expanded to other areas of the country in order to estimate the amount of nuclear fallout people were subjected to from the atmospheric testing of nuclear weapons. The non-worker tissue program ended in 1980. Nearly 1,000 decedents had tissues removed during their autopsies and sent to LANL by coroners.

The LAHDRA project team considers the human tissue sample data associated with residents of the Los Alamos area important because they can support the characterization of public exposures that resulted from LANL releases of plutonium during the initial decades of the facility's operations. In the past, when LANL reported results from the human tissue program, comparisons were made between various areas of the country. Samples from New York City were taken in the 1967-1968 time frame while samples from all other areas of the country (other than near Los Alamos) were taken only over the 1974 -1975 time frame. By that time, plutonium releases from LANL had been greatly reduced by the installation of HEPA filters on the various exhaust points. Consequently, worldwide fallout from weapons testing became an increasingly important source of plutonium exposure for Los Alamos residents. Individuals who arrived in Los Alamos after the 1960s might be expected to have mostly experienced intakes of nuclear fallout from weapons testing while people who arrived earlier could have inhaled or ingested greater amounts of plutonium from LANL releases.

The comparisons LANL staff have published have considered only the Los Alamos data for individuals who died in those limited years (1974-75 or 1967-68), to support comparison with the datasets collected from other parts of the country, since cases from New Mexico for earlier years would have been exposed to different levels of nuclear weapons testing fallout. Since there are only a few cases for those years, data from early and late arrivals; men and women; old and young; etc. were combined. When the combined cases data from these few years are compared to other areas of the country, the variability is so great that one cannot see if there was a difference between Los Alamos and other areas or not. From this result, LANL has asserted that there are no measureable differences between Los Alamos and other areas of the country. While this statement is correct, the LAHDRA team believes that it is misleading.

The data have been analyzed by Los Alamos to demonstrate that the differences in median values of plutonium concentration in tissues between states in the U.S. were small. However, the autopsy results from deaths at the Los Alamos Medical Center (designated as either Los Alamos residents or residents of Northern New Mexico) were generally the highest median values for nearly all organs compared to other states. Although other tissues were sampled, the LAHDRA project team is primarily interested in the results from the liver, skeleton, and lungs. The lungs provide information about plutonium inhaled in the last few years prior to death, while plutonium accumulates in liver and skeleton and provides an estimate of the total plutonium inhaled over a person's life. Because of relatively slight differences in the time (decades) that plutonium remains in either the liver or skeleton, it is possible to observe differences between people who were exposed to plutonium long ago and people who had more recent exposures.

The LAHDRA Project located and copied the death certificates from workers and residents of the Los Alamos area who contributed samples to the program (LANL 1978). The addresses of many of these individuals were obtained from cross referencing with the yearly listings in the telephone directories

maintained by the Los Alamos Historical Society and from other LANL documents and public records. The logbooks from the human tissue sample program and solutions of many of the sampled tissues were transferred by LANL to the United States Transuranium and Uranium Registries (USTUR) after the program ended. USTUR maintains them still today.

The exposure to fallout plutonium in an area would be broadly similar for most individuals who share similar lifestyles. However, the exposure to releases from plutonium facilities would not be similar, since individuals residing closer to the facility would generally have experienced greatest exposure to releases. These individuals might be a small subset of the total population. This subset, individuals residing close to a nuclear facility, might not significantly alter the median value of a dataset, especially when small numbers of samples are all the data that are available.

Analysis of the Autopsy Program Results by the LAHDRA Project

The LAHDRA staff attempted an independent analysis of the autopsy program results (Shonka 2004). This effort demonstrated that excess plutonium is present in non-worker residents of Los Alamos over what would be expected from global fallout from nuclear weapons testing. It also established and tests a method for uncovering the history of residence locations for autopsy cases. This history establishes the range and bearing from LANL release points along with the years of occupancy at each residence. This method could be used to reduce the uncertainty in retrospective dose reconstructions and possibly permit use of the autopsy data for bounding LANL releases.

The data from the residents who were present in Los Alamos can be used to estimate exposures for any resident of Los Alamos and also be used to provide upper and lower bounds on the plutonium source term from LANL operations. A full analysis of the data would require that the range and bearing from significant release points at Los Alamos, along with the time dependent source term, be incorporated into a model. Additionally, the date of death should be used in correcting the autopsy results for fallout.

From the results of this calculation, the median estimated exposure is a factor of 5 times higher in the long-term residents, while the geometric standard deviation is reduced by 20% from that of all Los Alamos residents taken as an aggregate population. This implies that stratifying the population results can significantly improve (that is, reduce the uncertainty) of the estimate of the potential exposures that an individual in Los Alamos received from past operations. The current model does not remove the range and bearing impact on the results, and further improvements are suggested.

Another use of this analysis would be the application of this method to estimate worker exposure for LANL workers who were not considered plutonium workers, and did not receive routine internal dosimetry.

Methods

The method used in this calculation was as follows:

1. Enter the data from the 1979 Health Physics journal paper (McInroy et al. 1979).
2. Conduct a public records search for information on Los Alamos residents in that journal article.
3. Calculate the ratio of deposited plutonium in the liver vs. vertebrae.
4. Plot the standard deviation of Pu Ratio for the populations of Los Alamos and Denver.
5. Draw conclusions about the individual cases in Los Alamos and possibilities of exposure.

Dose Estimates from Exposure of Organs to Plutonium

The autopsy data are provided for various organs in units of disintegrations per minute (dpm) per kg of organ. The following material is presented to assist in understanding what these units (dpm kg^{-1} organ) mean in terms of dose or risk. A fraction of the plutonium present in inhaled air is retained in the lung. The lung retains the plutonium for about a year or a year and one-half. Thus, the autopsy data for lung tissue largely reflects the plutonium air concentration for the last few years prior to death. Since most of the autopsies are from the 1960s and 1970s, the lung data largely reflect atmospheric fallout from the testing of nuclear weapons. The largest plutonium releases from Los Alamos appear to have occurred in the 1940s and 1950s. This plutonium, if measurable, would no longer be present in lung tissue.

The International Commission of Radiological Protection (ICRP) Report No. 30 model of plutonium behavior in the human body (ICRP 1979) distributes plutonium present in systemic circulation, with 45% going to the liver, 45% to bone, and the remainder going largely to excretion. Small fractions are assigned to other organs. The liver and skeleton retain the plutonium for decades. Reference Man (ICRP 1975) notes that Thoracic Vertebrae are 75% trabecular, the spongy bone in which marrow resides. Thus, the vertebrae and liver are appropriate tissues to sample to measure plutonium deposited in an individual over a long period. The program at LANL sampled these two tissues, along with other tissues such as lung.

The autopsy data are provided in dpm kg^{-1} organ. It may be of some use to understand the potential doses that are involved with the measured data. The dose, in rem per dpm kg^{-1} skeleton, can be derived as follows: a systemic uptake of 1 dpm ultimately results in 0.45 dpm in the skeleton or liver. The liver has a mass of 1.8 kg in Reference Man, resulting in 0.25 dpm kg^{-1} in liver tissue for each dpm that is incorporated into the body.

A conversion for the skeleton depends on the type of tissue sampled. The entire skeleton ranges from 10% to 20% trabecular bone by weight. If the tissue sample had the same proportions, one could divide by about 2 kg (or 20% of the 10 kg total mass of skeleton) to yield a value of 0.225 dpm kg^{-1} skeleton.

This value is close to that for liver. It has also been noted that the plutonium concentration in bone (from humans) is inversely proportional to the percent bone ash (McInroy et al. 1979). Plutonium is concentrated in the trabecular bone rather than hard, compact cortical bone. Each person is, of course, unique and their weights are not the same as the average that is expressed in Reference Man. The LANL compilations provide the actual dpm kg^{-1} organ, and express the data as if the individual had the same weight organ as reference man.

The dose resulting from a 1 dpm systemic uptake depends on the chemical form of the intake (and of course the isotope, particle size, etc.). For inhalation of ^{239}Pu oxide, Federal Guidance Report No. 11 asserts a dose factor of 8.21×10^{-04} Sv Bq^{-1} for bone surfaces, which converts to 1.37 mrem dpm^{-1} (intake) (USEPA 1988). Dividing 1.37 mrem by 0.225-dpm kg^{-1} skeleton then gives 6 millirem committed bone dose per dpm kg^{-1} skeleton.

The committed effective dose equivalent (CEDE) is a measure of radiation exposure that estimates risk by adding the dose from all of the organs (weighted for their risk for cancer) for as long as the radioactive material will be present in the body. On the basis of CEDE, the value for ^{239}Pu oxide is 0.6 mrem CEDE per dpm kg^{-1} skeleton, or 0.6 mrem CEDE per dpm kg^{-1} liver. For more soluble forms (inhalation Class W), the values for ^{239}Pu are 16 and 0.9 mrem per dpm kg^{-1} skeleton for bone surfaces and CEDE, respectively. Values for ^{238}Pu are similar to those for ^{239}Pu. A simplification that expresses the results in the right "ballpark" would be that 1 dpm kg^{-1} results in approximately one mrem CEDE for either liver or vertebrae results from the autopsy program.

Fallout Levels of Plutonium

The plutonium deposition from worldwide fallout in the Los Alamos area has been reported by LANL (Purtymun et al. 1990). Soil and river sediment samples were taken. The data were reported in units of concentration, fCi g^{-1}. One can convert the concentration measured in soil samples to areal deposition by multiplying the concentration by the mass of soil sampled and dividing by the total area of the samples. This conversion is needed to be able to compare the LANL data with that taken by the Environmental Measurements Laboratory (EML) as reported by Krey for the Denver area (Krey et al. 1976). Krey reported fallout for the Denver area as 1.7 ± 0.5 mCi km^{-2}. Krey's data did not include the contribution to fallout from Chinese testing in the late 1970s that may be present in the LANL data from the early 1980s. Krey's data also would not have included any weathering that might have occurred between the time of the Denver samples and those taken around Los Alamos. Both of these minor influences would likely offset one another, since weathering would tend to decrease the values and the Chinese testing would tend to increase the values.

Each site sampled by LANL consisted of a square area 9 m on each side, with soil collected from each corner and the center. Each sample was 7.5 cm in diameter and 5 cm deep. The samples were combined to form a composite sample. The total volume of soil collected was 1100 cm^3, which would weigh nearly 2 kg at an estimated average soil density of 1.8 g cm^{-3}. This is believed to be a conservative (high) soil density, which will overstate the fallout levels compared to values if a lower soil density value were assumed. The area collected by the LANL sampling method was 221 cm^2.

Plutonium release estimates put forward by LANL staff have been found in LANL documentation for 1948 – 1973. This total value is approximately 1.2 Ci (Andrews ca. 1973). This activity could contaminate an area of 1200 km^2 (assuming an unrealistic completely and uniform fallout distribution) to a level of 1 mCi km^{-2}. Thus, the sampling for background levels of plutonium in Los Alamos would have to be outside of a radius of 20 km to avoid including the impact of site operations in the results (a radius of 20 km includes approximately 1200 km^2).

As described by Purtymun, six sites within a 50-mi radius of Los Alamos were sampled in 1981 and 1983, and additional locations along the continental divide were sampled in 1986. In fact, the sampling locations were located at approximately a radius of 50 mi, or 80 km. Thus, the sampling locations were far enough removed from the site to avoid significant impact from LANL releases if the releases were on the order of curies.

In the Purtymun study, the average of the ^{239}Pu results for the six sites within the 50-mi radius near Los Alamos over two years was 8.75 ± 5 fCi g^{-1}. The data appear to fit a normal distribution with a better correlation than a lognormal distribution. In areal deposition, this value corresponds to approximately 0.8 ± 0.5 mCi km^{-2}. The integrated level of fallout plutonium for Los Alamos (Purtymun et al. 1990) appears to be about one-half of that for Denver (Krey et al. 1976). If the soil density is lower, then the fallout plutonium levels found by Purtymun are even smaller than one-half of those found by Krey near Denver.

Further Interpretation of the Autopsy Data

The autopsy data reported by McInroy et al. in 1979 in *Health Physics* shows that the cumulative frequency distributions of liver concentrations (dpm kg^{-1} liver) are nearly identical between Los Alamos and Denver. However, the vertebrae autopsy samples from Los Alamos are higher than Denver, and their different slope indicates the plutonium has been in the body longer. These data are shown in Fig. 17-12 and Fig. 17-13. To facilitate comparison, the figures from McInroy et al. were superimposed on one another in those figures.

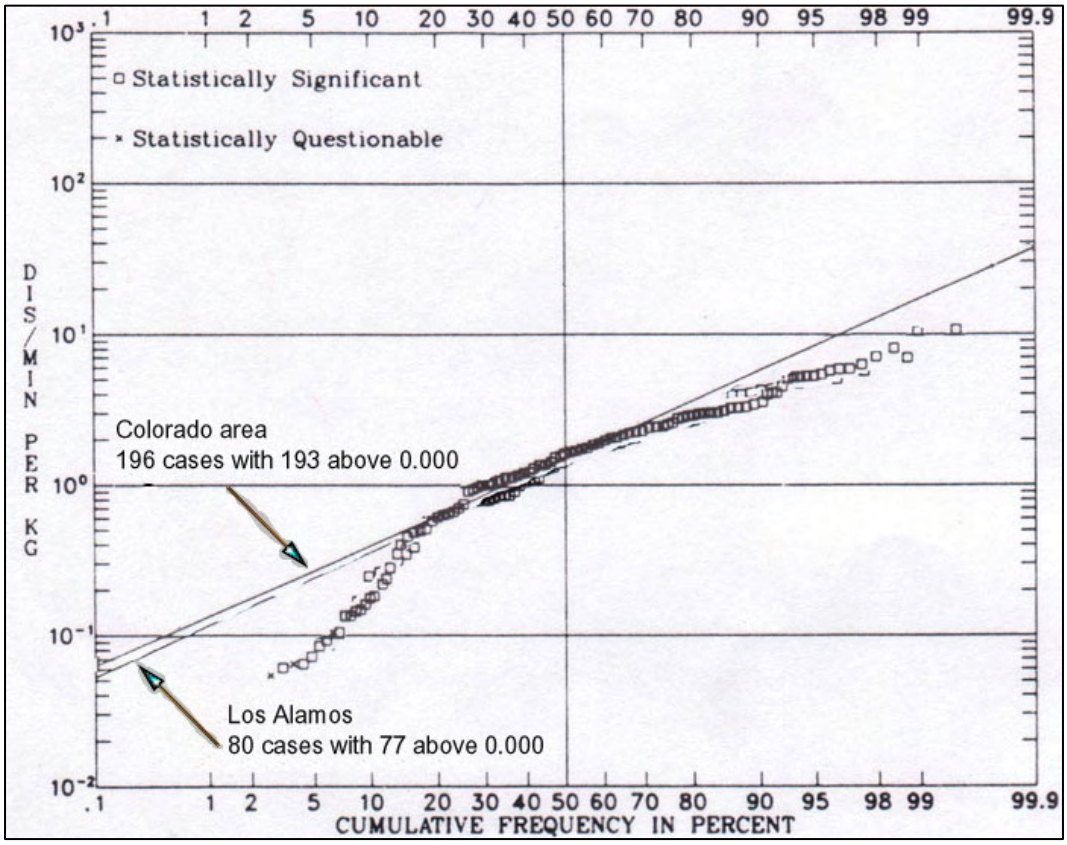

Fig. 17-12. Liver Autopsy Results

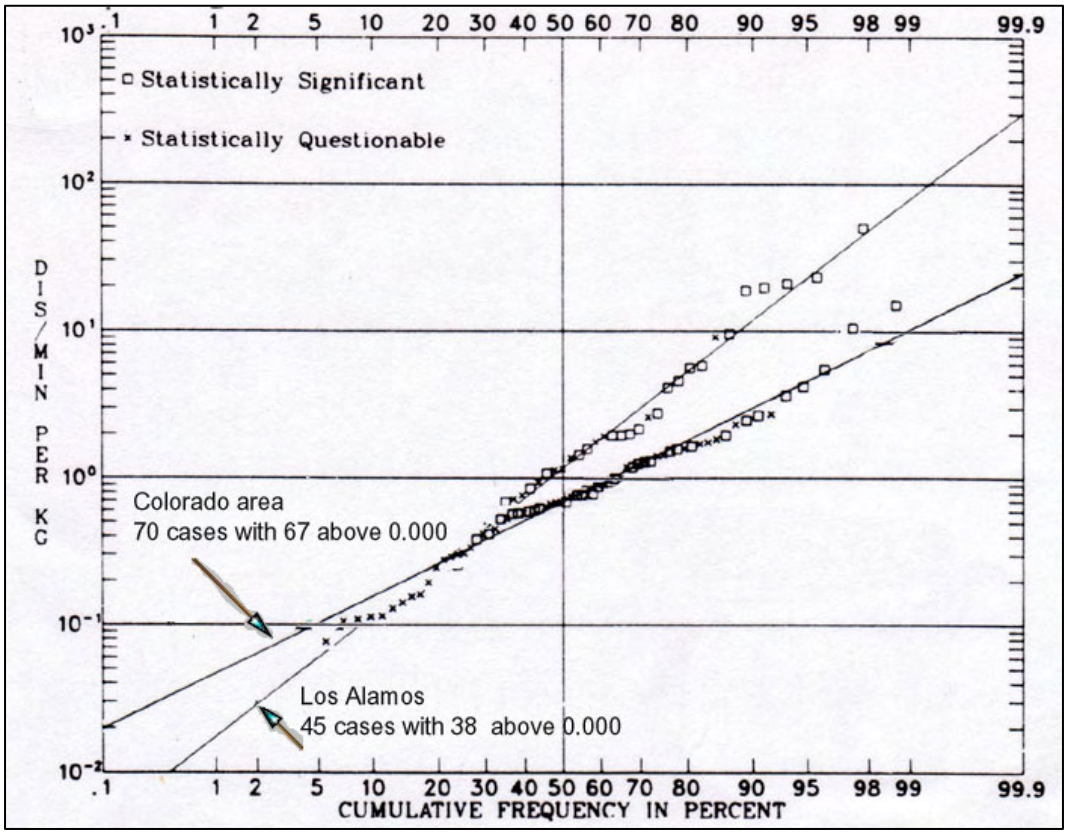

Fig. 17-13. Vertebrae Autopsy Results

If Los Alamos indeed had one half (or less) of the fallout as Denver, the liver results should show this. However, this is not the case. The liver data would seem to indicate the plutonium present at Los Alamos is roughly equal that of Denver. If one accepts the earlier fallout data from Purtymun and Krey, then this implies that the "extra" or "added" plutonium (that which makes the plutonium liver concentrations equal) is due to LANL emissions. The liver results show that autopsy samples from residents of Los Alamos appear to have "added" plutonium. If there were two distinct populations, one might expect to see a bend in the curve indicating added plutonium in the fraction of the population living nearest the release points. However, no bend is seen. This is probably due to the fact that if the added plutonium was due to facility operations, one might expect that the impact would be sporadic, with only a few individuals impacted based on the winds and other factors. It is likely that releases from the site were not sufficient to cause this "bend" in the CFD plot or that the inherent variability of various factors dominates the distribution and masks the presence of two populations.

Conclusions

The vertebrae results show differences between Los Alamos and Denver, with the differences occurring in the population with higher bone concentrations. This result also appears to be consistent with a hypothesis that releases at Los Alamos impacted the population.

The data also show significant divergence in the ratio of concentrations in the skeleton to that of the liver. Fig. 17-14 shows a cumulative frequency distribution graph for the ratio of vertebrae results to those of liver for all autopsy cases that had data for both organs. Four sets of data are shown, with two sets also fit to an exponential distribution. The two data sets with fitted exponentials are for Denver and Los Alamos. The other data sets are discussed in the next section.

The curves and data regarding vertebrae to liver ratios were not reported by McInroy et al. The information in Fig. 17-14 was computed as an element of this calculation. In general, the cases with positive results for both liver and skeleton would be the cases with highest reported data. The results from Denver appear to be log-normally distributed about a median ratio of 1.73. One individual (out of 38) had nearly 25-times as much plutonium in their vertebrae as in their liver.

The Los Alamos data (with a median ratio of 2.72) has three of the 17 results greater than 25, with one result approaching a ratio of 200 (off scale and not shown in Fig.17-14). The value of 2.72 indicates plutonium exposures that happened longer ago than those associated with the lower ratios. This is due to the difference in clearance time of plutonium from liver vs. vertebrae.

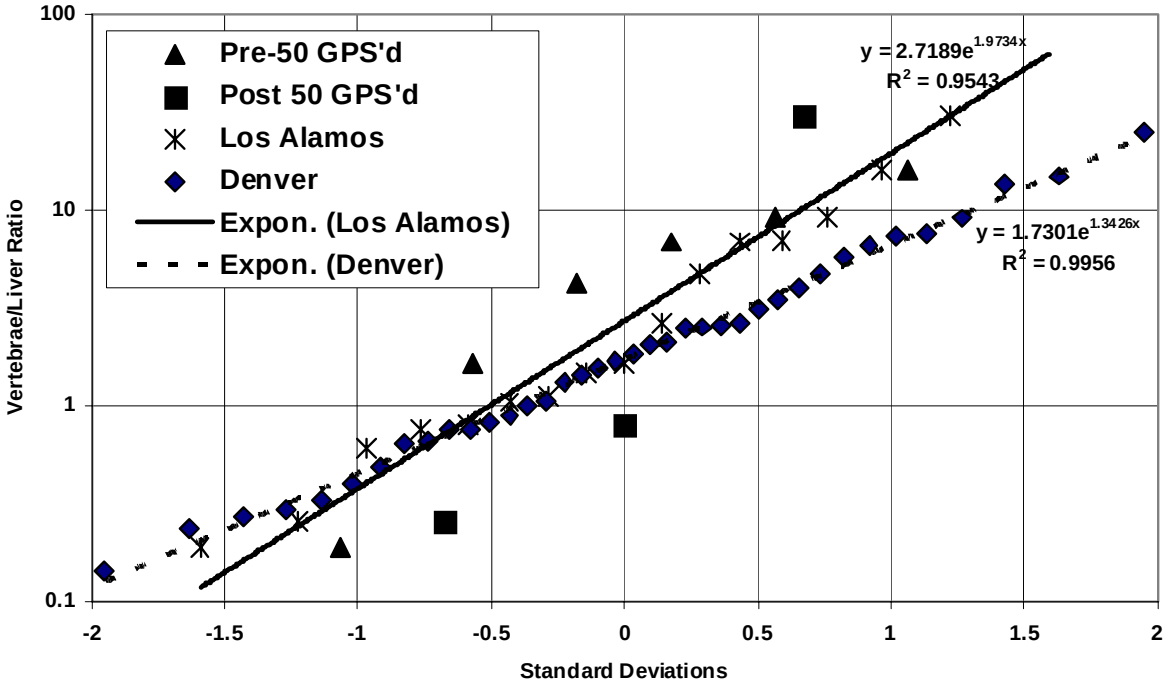

Fig. 17-14. Cumulative Frequency Distribution of Vertebrae-to-Liver Ratios

The ICRP model for plutonium behavior in the human body assumes that the skeleton retains plutonium with a biological half-life of 50 years, and the liver retains plutonium for 20 years (McInroy et al. 1979). When coupled to the results shown above, there appears to be an indication that not only is there added plutonium from site releases present in the autopsy samples obtained from Los Alamos, but also that the plutonium in Los Alamos residents appears to be due to exposures to plutonium that were earlier (longer ago) than atmospheric weapons testing exposures in the Denver population. It is important to note that the Denver population was *not* significantly exposed to plant releases from Rocky Flats. The downwind direction from Rocky Flats is predominately toward the east, and although there are persons living in this area, the population density is very low, and the likelihood that those persons were included in the Denver study is very low.

A vertebrae-to-liver ratio of one would be indicative of recent exposure. Larger ratio values would indicate that the exposure occurred at some point in the past, or that the exposures were higher in the past than more recent ones. An exponential function provides a good fit to the data shown in Fig. 17-14, which implies that the data are log-normally distributed. The median value, read from the chart at zero for the "X-Axis", shows a value of 1.73 for Denver, corresponding to less-aged exposures. Los Alamos shows a median value for the vertebrae-to-liver ratio of nearly 2.72. The geometric standard deviation is 2.3 times larger for Los Alamos compared to Denver. If the air concentration had been constant over

time, this would be a ratio indicative of exposure that began about 10 y prior to autopsy. Given the large values of the ratio for Los Alamos, these data indicate that exposures in the early years were higher than the later years.

Reduction of the Uncertainty in Autopsy Results

The publicly released autopsy results were published as blind samples, with no information concerning identity or residential history for each case. In a small city such as Los Alamos, relatively few deaths occurred each year. The LANL autopsy data had five attributes that could be used to establish the identity of the donor without obtaining the data from official or private records: (1) year of death; (2) resident of the City of Los Alamos; (3) sex; (4) age; and (5) cause of death. These five attributes were used to match a number of the autopsy cases to Los Alamos area residents.

Death certificates and an index key for participants in the autopsy program were found in the LANL Archives during 2006 (LANL 1978). The death certificates facilitated development of residence histories for each autopsy case. The documents included information regarding the "usual residence" of the decedent, as well as the "length of stay" in the place of death. In instances where the individual died in Los Alamos and was also a resident of Los Alamos, this value was considered to be the length of time that the person lived in Los Alamos.

For each participant who reportedly lived in Los Alamos, historical telephone directories were consulted for the years that the decedent was expected to have lived there. Directories were available for the years 1943-1944 and 1946-1969. None were available for 1945. Addresses were listed as street addresses beginning in 1948. In the 1943, 1944, 1946, and 1947 directories, addresses were listed as "T-numbers." Each house in the town was assigned a unique T-number. Historical maps of the original Technical Area were used to identify the exact location (latitude/longitude) of the T-number addresses. Several other sources were also consulted, including a September 1956 Atomic Energy Commission Albuquerque Operations Office directory, USAEC Los Alamos directories 1966-1972; a 1968-1969 Los Alamos school directory, and a 1964 Albuquerque Operations phone book.

For each name listed in the human tissue program information database, the "year of arrival in Los Alamos" and "length of time in Los Alamos" variables were used to determine in which directories each participant would likely be listed as a resident. In instances where the database contained two estimates of the "length of time in Los Alamos," the estimate corresponding with the greatest number of years was used in this search. For each year that it was believed the participant lived in Los Alamos, the corresponding phone directory was consulted to find their address for that year. In many cases, participants lived at a given address for more than one year and the variables "begin year" and "end year"

were associated with each address. The 2-3 years preceding and following the time period during which it was believed that the participant lived in Los Alamos were also checked in the telephone directories.

For participants that could not be located using the historical telephone directories, several other approaches were available. Obituaries printed in the Los Alamos Monitor, which was published several times per week, often provided detailed information regarding how long an individual lived in Los Alamos and, in some cases, where they lived. If address information was not directly provided, residential histories could also be determined by searching under family members' names during the relevant time periods. Ninety names were searched using this method and 36 matches were found. Marriage licenses often contained an address at the time of the marriage, but were also used to confirm familial relationships between some of the participants (such as father/daughter versus spouse). In some instances (particularly for women), the residential history could easily be tracked in the phone directories using the spouse's name. One hundred and two marriage licenses were searched for using this method and nine matches were found. Lastly, online genealogy services were used as an additional source of information.

In total, there were 236 autopsy cases for which tissue activity data were available, with 60 of those participants having been LANL employees. Associated with these participants were 809 residential locations, of which 677 were identified as addresses and 542 could be geocoded using an Internet-based service so that distance to D Building and DP West could be calculated. For some addresses, a global positioning satellite (GPS) unit was used to determine coordinates. In some cases, the historical address is no longer a residence. To support spatial analysis, geological coordinates were obtained for the addresses of the participants using Tele Atlas®. For each address, range from D Building and DP West were calculated.

Fig. 17-14 on Page 17-39 also shows two sets of data plotted as cumulative frequency distributions: pre-1950 data and post-1950 data. The plot of post-1950 data is uncertain due to there being only three cases with data for vertebrae and liver, one of which is the outlier. The pre-1950 data has a larger median and slightly smaller geometric standard deviation than that shown for all data from Los Alamos.

Additional Avenues for Investigation

Solutions of the original samples taken under the LANL human tissue analysis program, as well as logbooks associated with the program, have been maintained by USTUR for many of the autopsy cases. Because of that, it may be possible to determine how much of any autopsied individual's exposure was due to fallout or releases from LANL. A new method of measurement called Inductively Coupled Plasma Mass Spectrometry (ICP-MS) can distinguish between weapons-grade plutonium that has not been used in a nuclear weapon and plutonium from fallout that resulted from a nuclear detonation. USTUR has

performed an initial study of the method with promising results. This method and new analysis of the samples might permit accurate estimation of how much of the plutonium found in the tissues of any former Los Alamos resident was due to global fallout and how much was due to releases of plutonium from LANL.

LAHDRA project team members have discussed the case of a clerical worker who worked near D Building and whose tissues were obtained for the autopsy program. It was suggested that the case might be a limiting case for exposure to plutonium for residents, since that individual was closer to the D Building than nearby residences. LANL staff analyzed that case in detail in a recent publication entitled "Los Alamos Study of Early Los Alamos Internal Exposures to Plutonium" (Miller et al. 2008). The clerical worker case was summarized in Table 3, "Bioassay Data for Clerical Worker." LANL staff went on to conclude the following:

"Also of interest is the possible inhalation dose to members of the public in these days resulting from releases from the Los Alamos facilities. The dose was calculated for a clerical worker who was part of the Los Alamos plutonium autopsy study and had tissue burdens higher than those for others in the group of Los Alamos workers having low potential for exposure. A dose of this magnitude probably represents an upper limit for dose to workers who were not plutonium workers or who were merely town residents."

The data for the identified worker are summarized in Table 3 of that article. LAHDRA team members take issue with at least aspects of this analysis. First, the method used for assessing her exposure was a Bayesian method pioneered by LANL but not generally used for internal exposure elsewhere. In particular, the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) project administered by the National Institute for Occupational Safety and Health (NIOSH) has declined to use this method for LANL cases. The use of Bayesian methods requires *a priori* assumptions that affect the final result. While these assumptions are not sufficiently detailed in the Miller et al. article to reproduce their results, careful reading of the article appears to indicate that the variability of the LANL resident data set was not considered or included in the assessment. The assessment was purported to be for the clerical worker, but as can be seen with the data from Los Alamos residents, human variability is large and failure to consider it is a major issue with the analysis. Thus, while the result may apply to that individual, the study failed to address all of the uncertainties that would permit LANL to assert their conclusion that it also applies to the resident population.

After LAHDRA team members examined Table 3 of the Miller et al. paper, they were unable to find the stated clerical worker's bioassay data in any of the human tissue sample program publications or supporting materials obtained from Los Alamos. This issue was raised with LANL, and a response was provided that stated that LANL was unable to determine which case was represented, and also was unable

to find any matching data in the autopsy cases (Eisele 2008). They LANL staff went on to offer that the data came from a phone call to J. McInroy, the retired manager of the program. Table 3 of that publication might be in error, as the information presented does not agree with previous LANL publications of the data. LAHDRA project staff have been unable to determine if any of the other tables in that publication were also affected. The LAHDRA project team believes that this case is one of many that could be used to assess the impact of D Building releases on Los Alamos residents, but are not convinced that the data for the referenced clerical worker, if they can be located, will serve as a meaningful bounding case for any evaluation. If properly analyzed, the results and the results of other town residents would be useful for assessing the potential impacts of historical releases of plutonium from Los Alamos facilities.

LAHDRA team members and USTUR personnel have shared information concerning the autopsy results. A complete computer printout from the program dated 1991 has been obtained that can be reviewed against the publications that document the autopsy results. This printout has information in it that is protected under the Privacy Act, and cannot be released to the public. Attempts are underway to "clean up" the old computer output so that it can be scanned and optical-character-recognition processed to support entry into a spreadsheet to facilitate analysis. If that task is successful, the data from previous publications that LAHDRA currently uses (from the 1980 time frame) will hopefully be reconciled with the LANL data.

A review of other autopsy cases from New Mexico was made in an effort to review the possible plutonium exposure from the 16 July 1945 Trinity test. That review showed that there are no cases in the highest exposure contours of the downwind plume area as delineated by Quinn (Quinn 1990). The highest recorded plutonium levels were a woman from Truchas, New Mexico who was old enough to have been alive at the time of the Trinity test. Her liver concentration was 60 times higher than the average New Mexico resident. Truchas is next to the 1 mR h^{-1} contour line (at H+12 hours), which is does not reflect doses from inhalation or ingestion of radioactive material (Quinn 1990).

Prioritization of Waterborne Radionuclide Releases

Since 1944, operations undertaken at LANL have produced liquid wastes containing radioactive materials. Waterborne radioactive waste was released without treatment to Acid Canyon from 1944 to 1951 (see Fig. 17-15), when a treatment plant became operational. The LAHDRA team calculated Priority Indices for waterborne radionuclides in the following categories: total plutonium, ^{238}Pu, ^{239}Pu, ^{89}Sr, ^{90}Sr, tritium, gross alpha, and gross beta radioactivity. LANL also reported the following radionuclides at various times over the years; effluent data were tabulated but priority indices are not presented herein for ^{140}Ba/^{140}La (radioactive lanthanum), ^{227}Ac, ^{241}Am, ^{7}Be, ^{134}Cs, ^{137}Cs, ^{57}Co, ^{60}Co, ^{54}Mn, ^{22}Na, ^{83}Rb, ^{84}Rb, ^{75}Se, ^{85}Sr, and ^{88}Y. It is important to note that data were not available for all radionuclides for all years. For example, from 1962 through 1971, ^{239}Pu measurements were not reported, but total plutonium measurements were. The reasons for the changes in nuclides analyzed and/or reported over time are not known. In some later years, uranium measurements were made, but associated results were stated in terms of milligrams of uranium of unstated ^{235}U enrichment. As a result, since information that has been reviewed indicates that overall waterborne releases of uranium were relatively low, uranium was not evaluated in this assessment. The radionuclides named above are the only radionuclides for which historical compilations of liquid releases prepared by LANL were found.

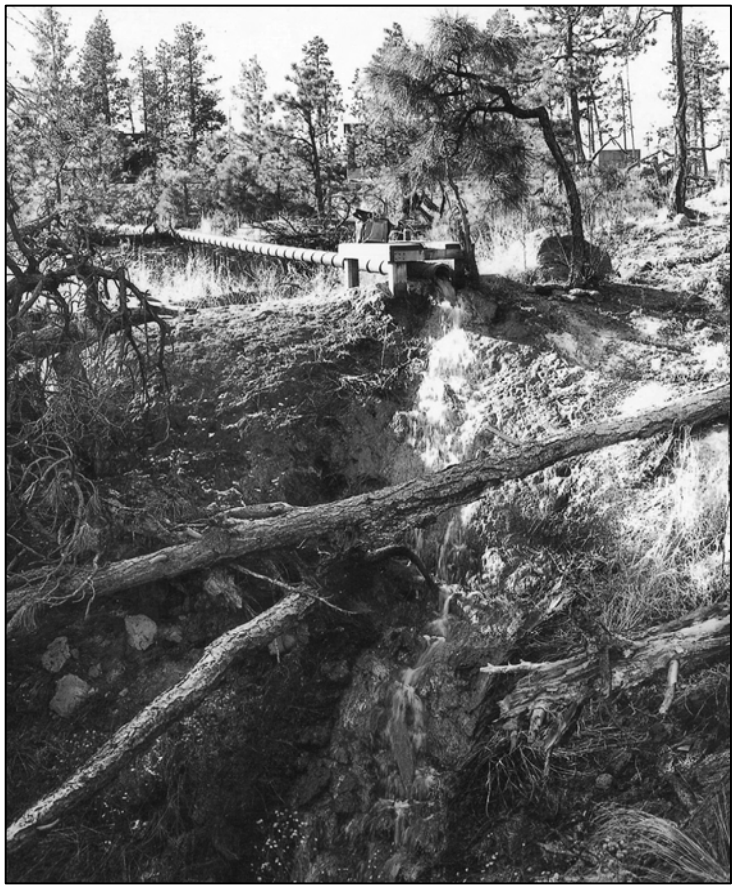

Fig. 17-15. During early Los Alamos operations, untreated liquid radioactive wastes were discharged to Acid Canyon through this pipe.

Data Sources

Three main data sources for waterborne radioactive effluents from LANL operations were found by the LAHDRA team:

- (Andrews ca. 1973) – "Joe Graf Binders" 1 and 2– Two binders of documents assembled by LANL Environment, Safety, and Health (ES&H) staff for group leader Joe Graf in the early 1970s that document releases from LANL before 1973. This was done to support development of a draft site-wide Final Environmental Impact Statement (FEIS). The FEIS was finally published in 1979. The documents assembled in these binders include records of room air concentrations, stack monitoring data, ES&H reports, and miscellaneous memos.
- (LAHDRA 2000) – Excerpts and compilations of AEC-789T "Radioactive Effluent/Onsite Discharges/Unplanned Releases" forms.
- LANL Annual Environmental Surveillance Reports from 1971-1996. These contain effluent information for TA-21, TA-50 and TA-53 waste treatment plants. Data from these published reports took precedence over other data that were found (LASL 1971, 1972a, b, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, LANL 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993a, 1994, 1995, 1996, 1997).

Priority index (PI) values were calculated by computing the volume of liquid that would be required to dilute the annual activity released to be equal to the worst-case maximum effluent concentration documented in Title 10 of the Code of Federal Regulations, Part 20 (USNRC 2003). The priority indices are intended to be guidelines for determining if a nuclide set requires further iterations of calculation and refinement, or if it warrants lower priority relative to other radionuclides (O'Brien and Burmeister 2004). For example, a PI of 10^6 indicates that 1 million L of liquid (water) would be required to dilute the released material to a concentration equal to the maximum effluent concentration. The priority index approach does not consider dilution and dispersion that can occur between the release point and points of potential public exposure. Although the lowest available (most conservative) effluent concentration limits are used, the priority indices do not otherwise address uptake factors. They do not consider decay in transport, which means as calculated, the priority index approach would tend to overstate the importance of short-lived materials. Within these limitations, PIs provide a simple tool for establishing the relative importance of various liquid-borne releases.

Priority Index was calculated as follows:

$$Priority\ \ Index\left(PI, L\right) = \frac{Total\ Nuclide\ Activity\ \ Released\ in\ \mu Ci\ y^{-1}}{Maximum\ \ Effluent\ \ Concentrat\ ion\ in\ \mu Ci\ mL^{-1}} \times 1{,}000\ mL\ L^{-1}$$

The maximum effluent concentration values shown in Table 17-9 were used (USNRC 2003). The concentration limit used for gross alpha radioactivity was the value for ^{239}Pu, which has the same value as ^{238}Pu, and the value for ^{89}Sr was used for prioritizing releases of gross beta radioactivity.

Table 17-9. Maximum Effluent Concentrations Used for Waterborne Radionuclide Prioritization

Nuclide Category	Maximum Effluent Concentration (μCi mL^{-1})
Gross Alpha Radioactivity	2.00×10^{-8}
Gross Beta Radioactivity	8.00×10^{-6}
^{3}H	1.00×10^{-3}
Plutonium	2.00×10^{-8}
^{238}Pu	2.00×10^{-8}
^{239}Pu	2.00×10^{-8}
^{89}Sr	8.00×10^{-6}

For the years 1948 to 1996, LANL liquid waste and effluent data were collected and analyzed by the LAHDRA project team. No summary data were found for the years 1974, 1975, or 1976. Given the releases in years preceding and just after that period, and considering the operational history documents that were reviewed, it is considered unlikely that releases during these missing years would significantly change any of the conclusions of this prioritization if they were found. A Microsoft Access® database was created to tabulate the effluent data that were captured and to link them to specific LANL documents that were assembled by the LAHDRA project team. In most cases, these documents are available as scanned document images as Adobe Acrobat® Portable Document Format (PDF) files. The database records in turn link to associated document image files to allow viewing of the actual LANL references for the data of interest. That database is called the Off-Site Releases (OSR) database and contains information for both airborne and waterborne effluent data.

Summary of Results for Prioritization of Waterborne Releases

Table 17-10, Table 17-11, and Table 17-12 comprise the summary data for the prioritization of waterborne radionuclide releases from LANL. The first two tables present annual releases of the various radionuclides, in curies. The third table presents priority indices for each radionuclide on an annual basis, calculated as the dilution volume required for dilution of the reported release quantity to the MPC. It was determined that the radionuclides in Table 17-12 were relatively insignificant due to the very low activity reported; therefore in Fig. 17-16, the plotted nuclides of interest are Pu, ^{238}Pu, ^{239}Pu, ^{89}Sr, ^{90}Sr, ^{3}H, gross alpha, and gross beta radioactivity. In this calculation, a data cutoff of 1996 was used since it was

deemed that this was far enough into the modern era, and prioritization was primarily focused on earlier eras before treatment and monitoring capabilities had developed.

Plutonium: Waterborne plutonium effluent data throughout the years have been reported as Pu, ^{238}Pu, or ^{239}Pu. During the very early years of LANL operations, the constant value reported for plutonium would suggest that there was one number that was "spread" among those years as an estimate. In later years, for which plutonium measurements were specified for several nuclides including ^{239}Pu, the LAHDRA project team entered the values into the database as ^{239}Pu. For instance, for 1993, plutonium was reported as Pu-238,239,240 and was entered into database as ^{239}Pu. Then again in 1994, plutonium releases were reported as Pu-238,239,240, but as ^{238}Pu and ^{239}Pu for both 1994 and 1995. In this case, the plutonium was entered as ^{238}Pu and ^{239}Pu. Separate radionuclide reporting was used whenever possible. The priority indices for plutonium range from approximately 10^7 to around 10^{11}. See Table 17-10 for annual release totals in curies (Ci) and Table 17-12 for priority indices (dilution volume, L).

Strontium: The priority index values for strontium range from 10^5 to 10^9. It is important to note that LANL changed reporting conventions for strontium several times. Sometimes ^{89}Sr and ^{90}Sr were reported separately, and sometimes they were not. In the later years, when ^{89}Sr is not reported separately, the strontium values were recorded as ^{90}Sr in the database by the LAHDRA project team. This may result in increased PI values for ^{90}Sr, but since the MPC for ^{90}Sr is lower than that for ^{89}Sr, this is a conservative assumption. Note that from 1989 to 1995, ^{89}Sr was either not in the compilations or was reported as Sr-82, 85, 89, and 90 all in one. These data were entered into the database as ^{90}Sr. That is why ^{89}Sr does not show data points in Fig. 17-16 for those years. Subsequently, it appears that ^{90}Sr has increased in priority relative to ^{89}Sr for these years. See Table 17-10 for annual release totals in curies (Ci) and Table 17-12 for priority indices (dilution volume, L).

Tritium: The PI values for tritium range from 10^6 to 10^8. Based on the currently available information, it would appear that tritium warrants lower priority than the other radionuclides. See Table 17-10 for annual release totals in curies (Ci) and Table 17-12 for priority indices (dilution volume, L).

Other Radionuclides: In Table 17-11 there are reported effluent values for other reported radionuclides. PI values calculated for these radionuclides ranged from 10^4 to 10^8, except for one ^{227}Ac value at 10^{11} and several ^{241}Am values of 10^9. There were a number of these radionuclides present, but none in concentrations that would yield greater priority indices than the primary nuclide set. The information for these "other" radionuclides is included for completeness.

Conclusions regarding prioritization of waterborne radionuclides

It is important to note that the information compiled here is for waterborne effluents. The current results indicate that, based on the assembled information as evaluated to date, plutonium would warrant the highest concern for waterborne radionuclide releases. It is not yet possible to definitively address the relative importance of waterborne effluents versus airborne effluents. It can be noted that, in general, pathways for public exposure from liquid releases appear to have not been as complete as those for airborne releases, due to the ephemeral nature of surface water flow in many cases, with a large part of off-site transport possibly occurring during heavy rains or runoff from periods of snow melting.

Comments and Issues

In the later years, when plutonium or strontium radionuclides were not listed by nuclide separately, values were entered into the database as ^{239}Pu and ^{90}Sr, respectively. This may have result in increased PI values for ^{239}Pu or ^{90}Sr. Since the maximum effluent concentration values for these radionuclides are lower than for their sister radionuclides ^{240}Pu and ^{89}Sr, this was a conservative assumption. There were two years (1970 and 1971) for which gross gamma radioactivity was reported (LAHDRA 2000); however, because LASL's Annual Environmental Surveillance report for 1971 did not include gross gamma measurements, the data on gross gamma for 1970 and 1971 were not included in this work.

Table 17-10. Waterborne Radionuclide Releases from LANL (Ci) Based on LANL Compilations [a]

Year	Pu	Pu-238	Pu-239	Sr-89	Sr-90	Sr-89, Sr-90	H-3	Gross Alpha	Gross Beta
1945	1.02E+00		3.50E-03	6.05E-02	1.88E-01		3.00E+00		
1946	1.02E+00		3.50E-03	6.05E-02	1.88E-01		3.00E+00		
1947	1.22E+00		3.50E-03	6.05E-02	1.88E-01		3.00E+00		
1948	1.22E+00		3.50E-03	6.05E-02	1.88E-01		3.00E+00		
1949	1.22E+00		3.50E-03	6.05E-02	1.88E-01		3.00E+00		
1950	2.02E+00		3.50E-03	6.05E-02	1.88E-01		3.00E+00		
1951	2.41E+00		3.50E-03	3.05E-02	1.77E-01		3.25E+00	2.45E-03	
1952	8.01E-01		3.50E-03	2.05E-02	1.73E-01		5.00E+00	4.11E-03	
1953	2.24E-03		3.50E-03	2.05E-02	1.73E-01		5.00E+00	4.97E-03	
1954	3.21E-03		3.50E-03	2.05E-02	1.73E-01		5.00E+00	5.42E-03	
1955	3.14E-03		3.50E-03	2.05E-02	1.73E-01		5.00E+00	1.06E-01	
1956	1.81E-03		3.50E-03	1.89E+00	5.03E-01		5.00E+00	1.07E-01	2.30E-01
1957	1.94E-03		3.50E-03	4.47E-01	2.47E-01		5.00E+00	1.68E-02	2.33E-01
1958	9.16E-02		3.50E-03	2.25E-01	2.01E-01		5.00E+00	9.46E-03	1.65E+00
1959	2.06E-03		3.50E-03	7.25E-02	1.81E-01		5.00E+00	9.84E-03	4.40E+00
1960	4.36E-03		3.50E-03	8.85E-02	1.85E-01		5.00E+00	1.34E-01	1.35E+00
1961	1.07E-02		3.50E-03	3.85E-02	1.75E-01		5.00E+00	7.55E-01	6.05E-01
1962	6.84E-03			1.80E-02	1.00E-03		5.00E+00	1.15E-02	1.22E+00
1963	6.81E-03			1.49E-01	3.98E-02		5.00E+00	2.84E-02	1.28E+00
1964	3.11E-03			6.07E-02	8.87E-02		3.20E+00	5.67E-03	2.67E+00
1965	4.48E-03			4.23E-02	6.18E-02		2.00E+00	7.30E-03	8.13E-01
1966	2.50E-03			2.44E-02	3.56E-02		2.00E+00	4.73E-03	3.98E-01
1967	6.58E-03			5.35E-02	1.34E-02		2.00E+00	1.51E-02	6.86E-01
1968	4.20E-03			3.26E-02	8.20E-04	4.89E-02		5.16E-03	3.26E-01
1969	8.36E-03			5.46E-02	1.31E-02	1.54E-03		4.33E-03	4.19E-01
1970	6.47E-03			1.54E-02	2.24E-02			8.28E-03	6.38E-01
1971	4.24E-03	2.70E-03	6.50E-04	4.68E-03	1.21E-02	2.80E-02		1.16E-02	1.09E+00
1972		7.86E-03	1.10E-03	4.15E-03	6.51E-03		9.60E+00	1.49E-02	3.96E-01
1973		8.60E-03	8.00E-04	4.90E-03	7.50E-03		1.90E+01	1.55E-02	9.99E-01
1974									
1975									
1976									
1977		2.63E-03	1.55E-03	2.29E-03	3.10E-02		3.97E+01		
1978		4.36E-03	2.05E-03	2.67E-03	1.05E-02		1.41E+01		
1979		1.76E-03	6.37E-04	6.10E-03	1.42E-02		3.31E+01		
1980		8.23E-03	1.31E-03	4.10E-02	1.81E-02		4.50E+01		
1981		3.35E-03	5.54E-02	4.16E-02	2.37E-02		1.74E+01		
1982		3.10E-03	1.68E-02	1.18E-02	1.34E-02		1.53E+01		
1983		1.10E-02	4.23E-02	5.68E-02	2.54E-03		1.04E+01		
1984		6.19E-03	8.23E-03	2.62E-01	7.03E-03		1.32E+01		
1985		3.92E-03	5.83E-03	9.01E-03	1.26E-03		7.02E+01		
1986		1.50E-03	3.60E-03	9.20E-03	6.90E-04		2.45E+01		
1987		1.40E-03	3.20E-03	6.40E-02	1.00E-03		1.11E+02		
1988		1.10E-03	3.20E-03	8.10E-02	2.00E-04		2.62E+01		
1989		6.00E-04	2.00E-03	1.80E-02	1.10E-03		4.10E+01		
1990		2.00E-04	6.00E-04		2.53E-01		1.20E+01		
1991		3.00E-04	1.00E-03		1.24E-01		1.06E+01		
1992		3.20E-04	3.90E-04		1.70E-02		1.06E+01		
1993			1.08E-03		3.40E-03		2.66E+00		
1994		2.80E-03	4.00E-04		3.70E-02		2.23E+00		
1995		3.40E-03	6.00E-04		6.00E-04		7.31E-01		
1996		2.25E-03	3.90E-04	6.60E-04	6.00E-04		1.02E+00		

[a] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

Table 17-11. Other Waterborne Radionuclide Releases from LANL (Ci) Based on LANL Compilations [a]

Year	Ba-La-140	Ac-227	Cs-137	Am-241	Be-7	Co-57	Co-60	Mn-54	Na-22	Rb-83	Rb-84	Se-75	Sr-85	Y-88	Cs-134
1945	2.00E-03														
1946	2.00E-03														
1947	2.00E-03														
1948	2.00E-03														
1949	2.00E-03														
1950	2.00E-03														
1951	2.00E-03														
1952	2.00E-03														
1953	2.00E-03	2.50E+00													
1954	2.00E-03														
1955	2.00E-03														
1956	2.00E-03														
1957	2.00E-03														
1958	2.00E-03														
1959	2.00E-03														
1960	2.00E-03														
1961	2.00E-03														
1962															
1963															
1964															
1965															
1966															
1967			1.20E-02												
1968															
1969															
1970															
1971															
1972															
1973			2.94E-01	1.50E-03											
1974															
1975															
1976															
1977			1.43E-01	2.14E-03											
1978			3.18E-01	4.03E-03											
1979			1.71E-01	5.27E-03											
1980			1.32E-01	5.75E-03											
1981			1.23E-01	2.44E-02											
1982			2.10E-01	1.88E-02											
1983			4.50E-02	3.84E-02											
1984			1.97E-02	9.04E-03											
1985			5.20E-05	5.54E-03											
1986			1.49E-01	3.20E-03	8.31E-01	5.02E-02	3.60E-03	1.89E-02	1.42E-01						
1987			8.10E-03	3.60E-03	3.30E-01	8.10E-02	8.50E-03	2.30E-02	8.90E-02						7.90E-02
1988			3.99E-02	3.70E-03		1.60E-02	4.00E-03	9.80E-03	1.90E-02						
1989			3.90E-02	4.10E-03	6.90E-02	5.40E-02	6.50E-02	1.43E-01	1.30E-01	2.30E-01	2.60E-02	1.10E-01	1.00E-01	1.90E-03	
1990			1.25E-02	2.70E-03			1.19E-02	1.30E-03			5.08E-01	5.30E-02		4.00E-04	
1991			6.70E-02	1.10E-03			1.00E-03	0.00E+00			4.50E-02	6.00E-03		6.00E-04	
1992			7.80E-03	8.90E-03											
1993			8.17E-03	1.12E-02											
1994			8.50E-03	3.10E-03											
1995			6.60E-03	1.40E-03											
1996			2.20E-03	1.99E-03											

[a] Note regarding scientific notation: 4.96E+05 equals $4.96 \times 10^{+5}$, which equals 4.96×100,000 or 496,000.

Table 17-12. Priority Indices for Waterborne Radionuclide Releases [a]

Year	Pu	Pu-238	Pu-239	Sr-89	Sr-90	H-3	Gross Alpha	Gross Beta
1945	5.12E+10		1.75E+08	7.56E+06	3.75E+08	3.00E+06		
1946	5.12E+10		1.75E+08	7.56E+06	3.75E+08	3.00E+06		
1947	6.12E+10		1.75E+08	7.56E+06	3.75E+08	3.00E+06		
1948	6.12E+10		1.75E+08	7.56E+06	3.75E+08	3.00E+06		
1949	6.12E+10		1.75E+08	7.56E+06	3.75E+08	3.00E+06		
1950	1.01E+11		1.75E+08	7.56E+06	3.75E+08	3.00E+06		
1951	1.20E+11		1.75E+08	3.81E+06	3.53E+08	3.25E+06	1.22E+08	
1952	4.01E+10		1.75E+08	2.56E+06	3.45E+08	5.00E+06	2.06E+08	
1953	1.12E+08		1.75E+08	2.56E+06	3.45E+08	5.00E+06	2.48E+08	
1954	1.61E+08		1.75E+08	2.56E+06	3.45E+08	5.00E+06	2.71E+08	
1955	1.57E+08		1.75E+08	2.56E+06	3.45E+08	5.00E+06	5.30E+09	
1956	9.05E+07		1.75E+08	2.36E+08	1.01E+09	5.00E+06	5.34E+09	2.88E+07
1957	9.70E+07		1.75E+08	5.58E+07	4.93E+08	5.00E+06	8.41E+08	2.91E+07
1958	4.58E+09		1.75E+08	2.81E+07	4.03E+08	5.00E+06	4.73E+08	2.06E+08
1959	1.03E+08		1.75E+08	9.06E+06	3.61E+08	5.00E+06	4.92E+08	5.50E+08
1960	2.18E+08		1.75E+08	1.11E+07	3.69E+08	5.00E+06	6.69E+09	1.68E+08
1961	5.35E+08		1.75E+08	4.81E+06	3.49E+08	5.00E+06	3.78E+10	7.57E+07
1962	3.42E+08			2.25E+06	2.00E+06	5.00E+06	5.74E+08	1.53E+08
1963	3.41E+08			1.86E+07	7.96E+07	5.00E+06	1.42E+09	1.60E+08
1964	1.56E+08			7.59E+06	1.77E+08	3.20E+06	2.84E+08	3.34E+08
1965	2.24E+08			5.29E+06	1.24E+08	2.00E+06	3.65E+08	1.02E+08
1966	1.25E+08			3.05E+06	7.12E+07	2.00E+06	2.36E+08	4.98E+07
1967	3.29E+08			6.69E+06	2.68E+07	2.00E+06	7.55E+08	8.58E+07
1968	2.10E+08			4.08E+06	1.64E+06		2.58E+08	4.08E+07
1969	4.18E+08			6.83E+06	2.62E+07		2.17E+08	5.24E+07
1970	3.24E+08			1.92E+06	4.47E+07		4.14E+08	7.98E+07
1971	2.12E+08	1.35E+08	3.25E+07	5.85E+05	2.42E+07		5.78E+08	1.36E+08
1972		3.93E+08	5.50E+07	5.19E+05	1.30E+07		7.47E+08	4.95E+07
1973		4.30E+08	4.00E+07	6.13E+05	1.50E+07		7.75E+08	1.25E+08
1974								
1975								
1976								
1977		1.31E+08	7.76E+07	2.86E+05	6.19E+07			
1978		2.18E+08	1.03E+08	3.33E+05	2.10E+07			
1979		8.81E+07	3.19E+07	7.63E+05	2.85E+07			
1980		4.12E+08	6.57E+07	5.12E+06	3.62E+07			
1981		1.68E+08	2.77E+09	5.20E+06	4.73E+07			
1982		1.55E+08	8.41E+08	1.48E+06	2.68E+07			
1983		5.52E+08	2.11E+09	7.10E+06	5.08E+06			
1984		3.10E+08	4.12E+08	3.28E+07	1.41E+07			
1985		1.96E+08	2.91E+08	1.13E+06	2.51E+06			
1986		7.50E+07	1.80E+08	1.15E+06	1.38E+06			
1987		7.00E+07	1.60E+08	8.00E+06	2.00E+06			
1988		5.50E+07	1.60E+08	1.01E+07	4.00E+05			
1989		3.00E+07	1.00E+08	2.25E+06	2.20E+06			
1990		1.00E+07	3.00E+07		5.06E+08			
1991		1.50E+07	5.00E+07		2.48E+08			
1992		1.60E+07	1.95E+07		3.40E+07			
1993			5.40E+07		6.80E+06			
1994		1.40E+08	2.00E+07		7.40E+07			
1995		1.70E+08	3.00E+07		1.20E+06			
1996		1.13E+08	1.95E+07	8.25E+04	1.20E+06			

[a] Note regarding scientific notation: 4.96E+05 equals $4.96\times10^{+5}$, which equals 4.96×100,000 or 496,000.

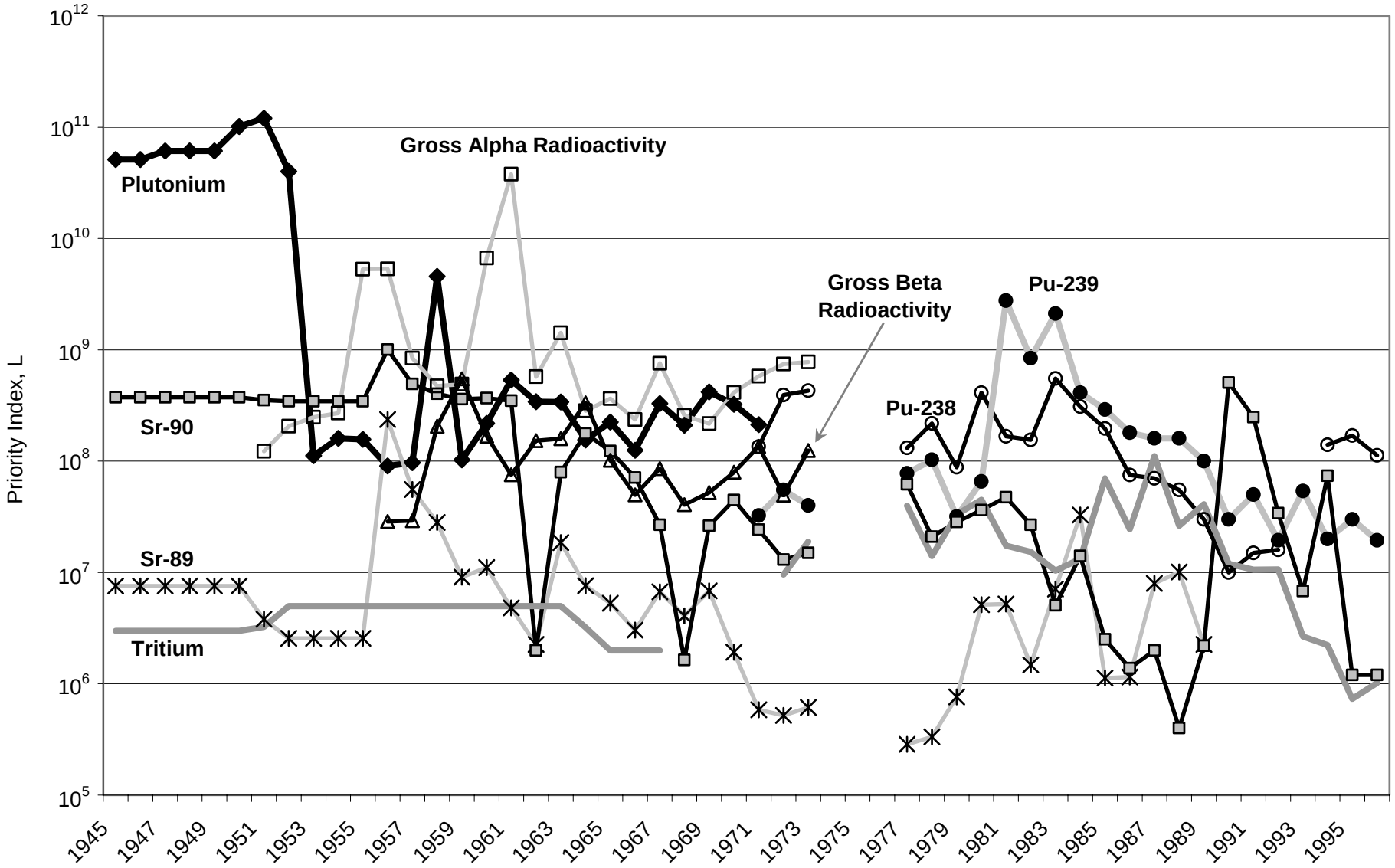

Fig. 17-16. Priority Indices for Waterborne Radionuclide Releases from LANL

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