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Selected Key Contaminant Sources from Los Alamos National Laboratory including Liquid Outfalls and Material Disposal Areas

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Introduction

This report summarizes the historic liquid outfalls that are considered the most likely sources of contamination present within the regional aquifer beneath Los Alamos National Laboratory. Tritium, perchlorate, chromium, nitrate, and high explosives are Laboratory-derived contaminants that are observed in the regional aquifer. In addition to these constituents, chlorinated solvents, dioxane[1,4-], barium, and boron have also been measured in overlying perched-intermediate groundwater (LANL, September 2006). The sources for these contaminants are almost certainly liquid effluents that were discharged into canyons over the Laboratory's sixty-year history.

Generally, the thick unsaturated zone beneath the Laboratory and the semi-arid climate lead to slow contaminant migration within the subsurface with estimated travel times from the surface to the regional aquifer ranging from centuries to millennia. However, Laboratory-derived contaminants have been detected in the regional aquifer at some locations. In order for detectible amounts of contamination to have reached the regional aquifer beneath the Laboratory within a few decades, several physical characteristics are required of the source and the disposal location. These required factors are:

- a large contaminant inventory, typically with liquid discharge
- mobile constituents
- a natural or anthropogenic (e.g., facility effluent) aqueous driver that occurred concurrent with and/or subsequent to the contaminant release
- a canyon release, which is an important factor for spatial and temporal variability in infiltration.

The combined conditions of a large, mobile chemical inventory with a topographically-controlled, focused water source are sufficient to drive contaminants through the thick unsaturated zone to the regional aquifer on the time scale of a few decades. For this reason, contaminant releases that meet these requirements are an immediate interest for local environmental protection. Toward this end, effluent water volumes and associated releases of the highly mobile constituents tritium, nitrate, perchlorate, chromium and high explosives (i.e., RDX) for the larger of the Laboratory outfalls are the focus of this summary. Adsorbing contaminants may reside in canyon sediments to become secondary sources that release over longer time periods than original outfall releases; these are not considered in this study because of their slower release. Inventory estimates for key Material Disposal Areas (MDAs) at the Laboratory are also presented in this summary for completeness.

This report is generated at the request of the National Academy of Sciences (NAS) review committee for "Technical Assessment of Environmental Programs at the Los Alamos National Laboratory". The summary is an evolving work as further archival information becomes available and techniques of mass estimation are developed. The long-term goal is to summarize outfall volumes and contaminant inventories for mobile

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contaminants released from some 16 to 20 outfalls. This information will continue to be useful in modeling studies and analyses of the Laboratory's groundwater monitoring network. However, this report summarizes release information compiled for only six outfalls and for key MDAs, as time permitted for the NAS committee's review schedule. In most cases inventory records are presented. However, we also describe some techniques that are being used for deriving contaminant masses from field observations and from assumptions about operating conditions where records are sparse or nonexistent.

Outfall Overview

Based on Laboratory operations that have occurred since the mid-1940's, the most likely sources of deep contamination are the four classes of liquid outfalls related to (1) radioactive liquid waste treatment, (2) high explosives machining operations, (3) sanitary waste treatment, and (4) other Laboratory operational releases, such as cooling tower outfalls or reactor leaks. Figure 1 indicates the most significant (either in terms of water volume or contaminant masses released) historic and current liquid outfalls that could potentially impact groundwater at the Laboratory; the major contaminants associated with each outfall are listed. Many smaller outfalls are considered secondary sources and not included in this map. The Bayo and Central sanitary treatment plants are current and historic plants operated by Los Alamos County that treated municipal wastewater, but contaminants from these plants may mingle with Laboratory-derived contaminants. For this reason, including these two sources is important for understanding observed nitrate (for instance) detections in the regional aquifer.

Contaminants from the point sources identified in Figure 1 disperse as they travel through the surface and subsurface environments toward the regional aquifer. For instance, surface water and near-surface perched alluvial groundwater spread laterally along canyons before further infiltrating the underlying vadose zone. Additional lateral spreading may occur along geologic contacts (permeability contrasts) and in perched intermediated zones within the vadose zone. Therefore, the *breakthrough* locations at the level of the regional aquifer extend beyond the original point-source release locations. Figure 2 shows the original outfall locations and potential breakthrough locations at the water table that might result from the combined point sources. These elongated breakthrough locations were developed based on field hydrologic conditions such as existence of alluvial groundwater, elevated vadose-zone moisture content and the presence of perched-intermediate groundwater. Previous and current contaminant distributions in alluvial groundwater were also used. In some cases, contaminant distributions in vadose-zone porewater, perched-intermediate groundwater and regional groundwater were used as well. When deciding upon the location of monitoring wells, the broader location at the water table may be more appropriate for well location than the specific point-source (outfall) surface configuration.

Contaminants at the water table have been observed at a few of the locations shown in Figure 2. Therefore, these locations are considered to have potential for near-term (now and within a few more decades) contaminant migration of mobile species to the regional aquifer. Note that this map does not include information about either vadose-zone contaminant travel times or potential future contaminant concentrations; rather, the map shows only areas (depicted as polygons) of potential, future breakthrough of contaminants from the vadose zone to the water table.

Liquid waste outfall volumes and contaminant releases

Table 1 summarizes six outfalls that have operated at the Laboratory and are suspected sources of groundwater contamination. These six outfalls represent fewer source locations than shown in Figures 1 and 2, but are summarized here to give the NAS review committee a sense of historic and current outfall volumes and contaminant releases. The table shows the periods of operation for the various outfalls and gives estimates of the total water volumes released. The TA-50 radioactive liquid waste treatment facility (RLWTF) and the TA-3 power plant are still active, and the outfall volumes presented are current through 2005. In addition, Figure 3 shows annual outfall volumes from 1945 through 2005 for effluents containing radioactive constituents. High-level observations from the information given in Table 1 and Figure 3 include:

- The combined power plant cooling towers and sanitary effluent releases at TA-3 to Sandia Canyon are the greatest effluent volumes. Recently, the power plant has significantly decreased operations, but the sanitary waste effluent continues to act as a water source of similar volume (approximately 200,000 to 300,000 gal/day) to Sandia Canyon.
- The TA-50 RLWTF has released the greatest volumes of treated radioactive waste effluent. However, the TA-45 outfall released outfall volumes similar to the higher-volume, early annual releases from the TA-50 outfall.
- The Omega West Reactor (OWR) leak was small volume compared to these other sources.

Table 1 also provides estimates for the total masses released for the mobile constituents associated with the six outfalls. Tritium and nitrate mass estimates are fairly complete, although uncertain. Time histories for tritium releases are given in Figure 4. Until recently, no records of perchlorate releases were kept; the perchlorate mass for the TA-50 RLWTF is derived from field data and from two mass-estimation techniques that are explained in the following section. RDX mass is also estimated as described below. High-level observations from the information given in Table 1 and Figure 4 include:

- The TA-50 RLWTF has released the largest amount of tritium of the sources discussed here. (We note that two mesa top material disposal areas (MDAs) are known to have greater inventories of tritium (Rogers, 1998).
- The Omega West Reactor (OWR) released notable tritium despite low effluent volumes because the concentration of leaking tritium (100,000 to 120,000 pCi/L) was high compared to other sources. Because the duration of the leak is unknown, the cited mass in Table 1 assumes that the cooling-system leak occurred over a maximum possible 36-year period (Rogers 1998); this value is provided as a maximum.
- Significant chromium was likely released at the TA-3 power plant into Sandia Canyon. The chromate mass is approximated based on sparse records indicating daily chromate usage and also likely operating conditions (discharge volumes and chromate concentration) in the power plant cooling towers. This will be refined as more information, including field data, is obtained during the chromium workplan investigations. The TA-3 power plant and the Sanitary Wastewater System (SWWS) effluents continue to provide a liquid driver at this location.
- Significant RDX was released at the TA-16 260 outfall. Significant surface soil containing RDX has been removed at this site.

Mass estimation techniques

Several methods are used to derive contaminant masses when original source information is sparse. The following describes techniques used to derive the perchlorate mass discharged from the TA-50 RLWTF, and the RDX mass released from the 260 Outfall at TA-16, both given in Table 1.

For the perchlorate mass, two methods illustrate that insitu contaminant masses can be evaluated when original source information is sparse.

(1) A mass balance based on measured vadose-zone porewater concentrations and moisture contents. The perchlorate mass in Mortandad Canyon has been observed to reside almost entirely within the vadose zone (LANL October 2006). Field data from 25 vadose-zone boreholes are extrapolated with earthVision software. The software is then used to estimate the perchlorate mass residing within this extrapolated contaminated zone, taking into account the vadose-zone moisture content. Figure 5 shows the estimated distribution of perchlorate in the vadose zone in Mortandad Canyon.

(2) Vadose-zone perchlorate and nitrate concentration profiles with depth are found to be correlated. The nitrate release history for the TA-50 RLWTF is well documented (Figure 6a) (LANL 2005 and LANL October 2006). As a result, the correlation between the perchlorate and nitrate field data can be used to estimate the original time-dependent perchlorate release history (LANL 2005). One complication to this technique is that an unknown quantity of nitrate loss through denitrification has occurred in the environment; perchlorate is assumed to be stable. Therefore, we needed to estimate the amount of nitrate lost to denitrification to derive bounding estimates for the original time-dependent perchlorate release history, as shown in Figures 6a and 6b.

For the RDX mass, five methods were used to estimate mass released.

(1) The first method assumes that RDX was released during machining operations at its solubility limit and multiplies this concentration by the NPDES estimates of outfall volumes. The NPDES volumes were point measurements measured shortly before the outfall was closed in 1996 and assumed to be 24-hour flow rates. These volumes were extrapolated backwards for the entire history of TA-16 Building 260 to arrive at the RDX mass for this method.
(2) The second uses soil concentrations and masses removed during a soil clean up performed below the outfall. This method is thought to yield a low estimate because much of the RDX is assumed to have migrated beyond the vicinity of the outfall. This estimate is not included in Table 1.
(3) The third method uses records based on machining operations and takes into account: hours of operation, cooling-water flow rates, solubility limit, and number castings per month. This estimate was complicated by the long and changing operations at the facility and by incomplete records, but accounts for a long-term data set.
(4) The fourth method was based on employee interviews that gathered information on cooling-water flow rates, wash-down rates, and shift and set-up operations.

(5) The fifth is a combination of methods 3 and 4. This method is thought to yield a conservative (high) estimate because (1) it assumes all water discharged was contaminated with RDX at its solubility limit, even though many parts that were machined did not contain RDX. (2) This method extrapolates data concerning machining times per part backwards to earlier years yielding a greater length of time than is realistic based on known operations.

Table 1 gives the range in total estimated RDX mass released at the 260 outfall, and Figure 7 shows the time history of releases based on four of the methods.

LANL Material Disposal Areas and Potential Release Sites

There are 25 material disposal areas (MDAs) and 902 potential release sites (PRSs) at LANL that contain contaminants with a potential to migrate in the environment. MDAs are generally near-surface disposal facilities located on mesa tops with waste buried in pits or shafts. When the waste was buried, the disposal technique was intended to be permanent. Table 2 lists nine key MDAs and their estimated radionuclide inventories compiled from various sources; Figure 2 shows the key MDA locations in relation to key liquid outfalls. Although all MDAs are potential contaminant sources, each lacks a potent aqueous driver (e.g., a liquid outfall) for rapid mobilization of hazardous and (or) radioactive contaminants further into the environment and, particularly, into the regional groundwater resource. Of the 902 PRSs, 478 have either suspected or confirmed radiological contamination from site operations, and 424 are non-radiological sites. All sites are evaluated and treated as necessary via best management practices to prohibit water run-on, infiltration, and sudden erosional release of contaminants. Evaluation and disposition of all sites is scheduled for completion by 2015.

Summary

Outfall volumes and releases of mobile constituents for the Laboratory's larger historic and current outfalls are being compiled for analyses of the Laboratory's groundwater monitoring network. Several different techniques are used to compile these data, and some of these are described. This report summarizes the current status of this compilation and was prepared as information for the NAS groundwater review. The report also presents inventory estimates for key MDAs.

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Rogers, D., 2001, Impact of Strontium-90 on Surface Water and Groundwater at Los Alamos National Laboratory Through 2000, Los Alamos National Laboratory Report LA-13855-MS, pp. 39.

Shuman, R. (URS Corp.), 2005, Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Material Disposal Area G (Tables 48 and 49).

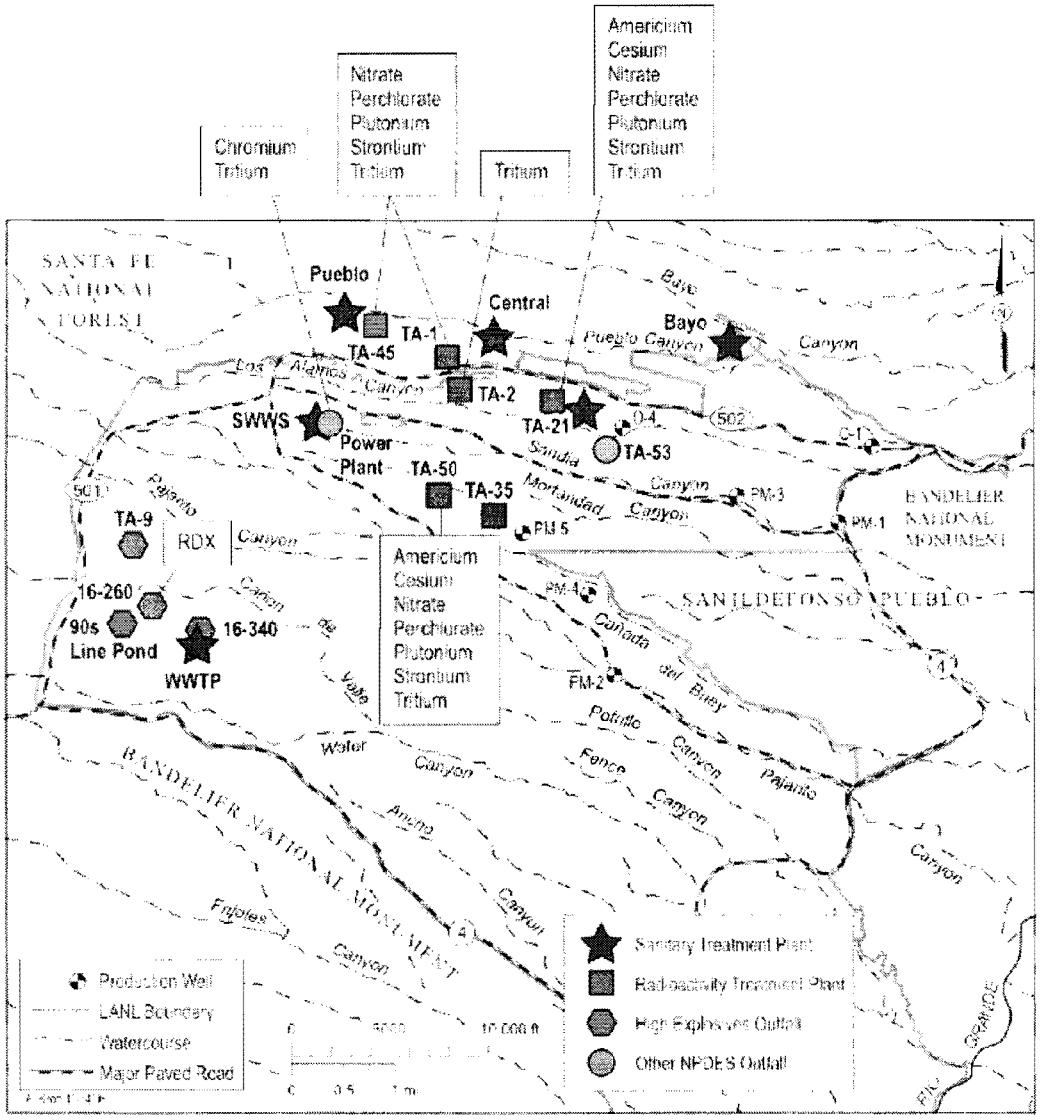


Figure 1: Major liquid release sources potentially affecting groundwater at the Laboratory (most sources shown are inactive). Key contaminants released are indicated.

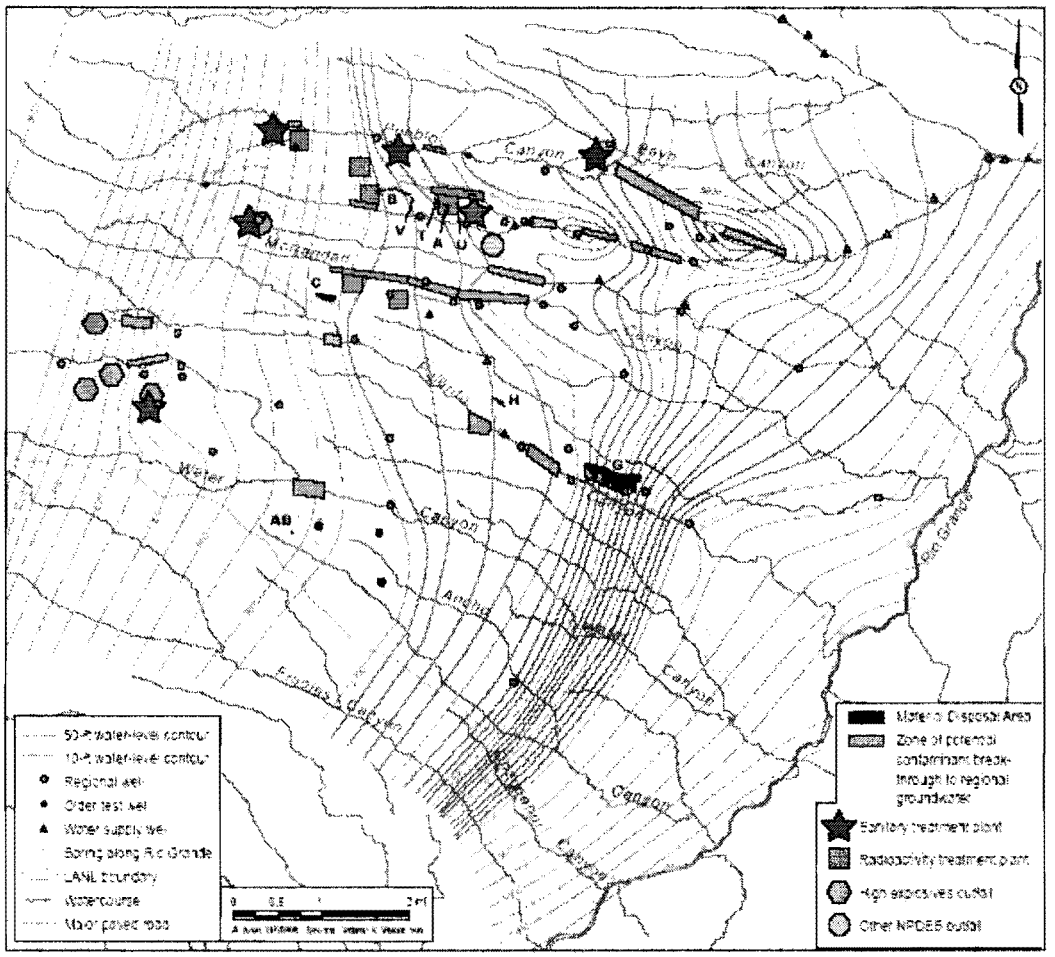


Figure 2. Major liquid release sources (from Figure 1) and key Material Disposal Areas (MDAs) B, V, T, A, U, C, H, G, and AB. Possible configuration of contaminant breakthrough at the water table resulting from dispersion from the major liquid point sources. Water-level contours for the regional water table.

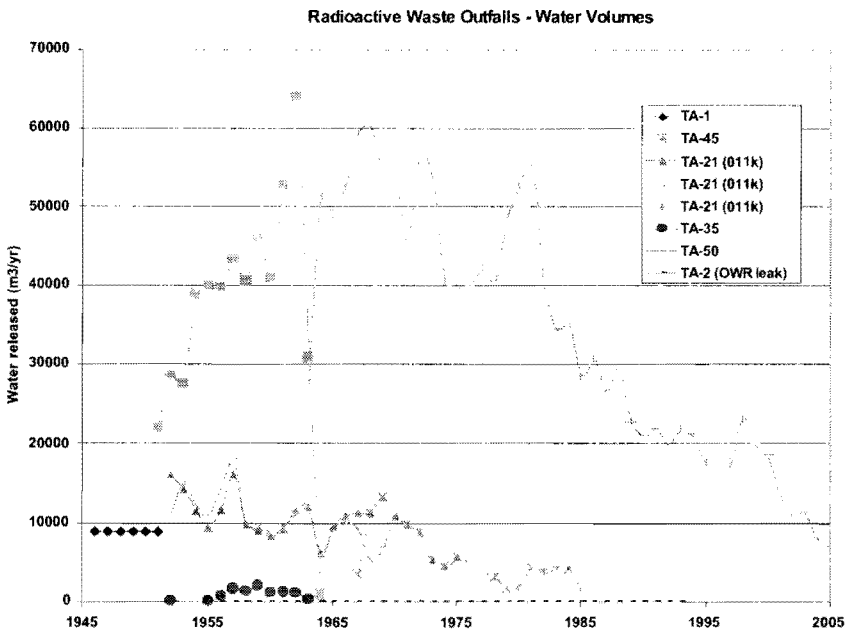


Figure 3. Effluent water volumes (m^3/yr) released at LANL outfalls with radioactive constituents (Purtymun, 1975 and LANL, October 2006)

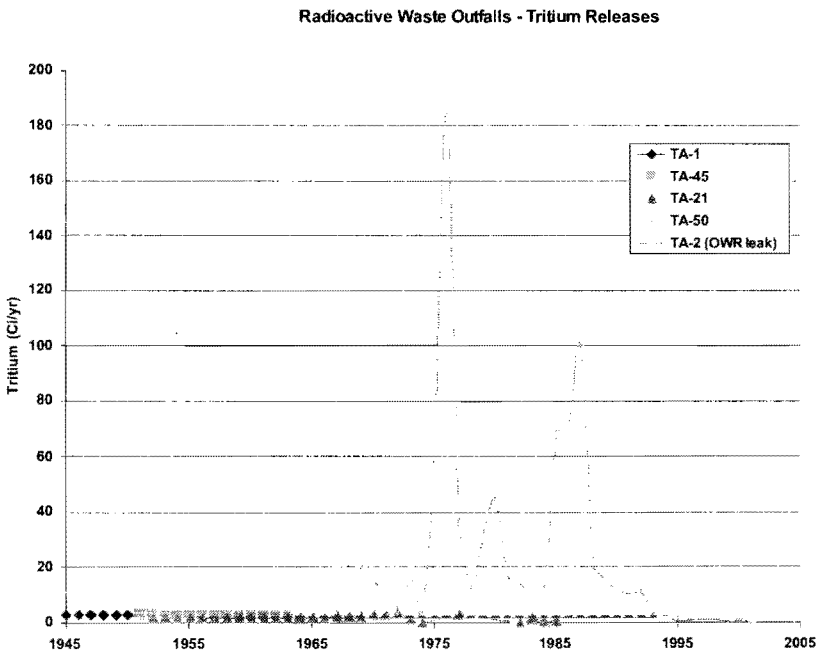


Figure 4. Tritium released (Ci/yr) at selected LANL outfalls (Purtymun, 1975; Rogers 1998 and LANL, October 2006)

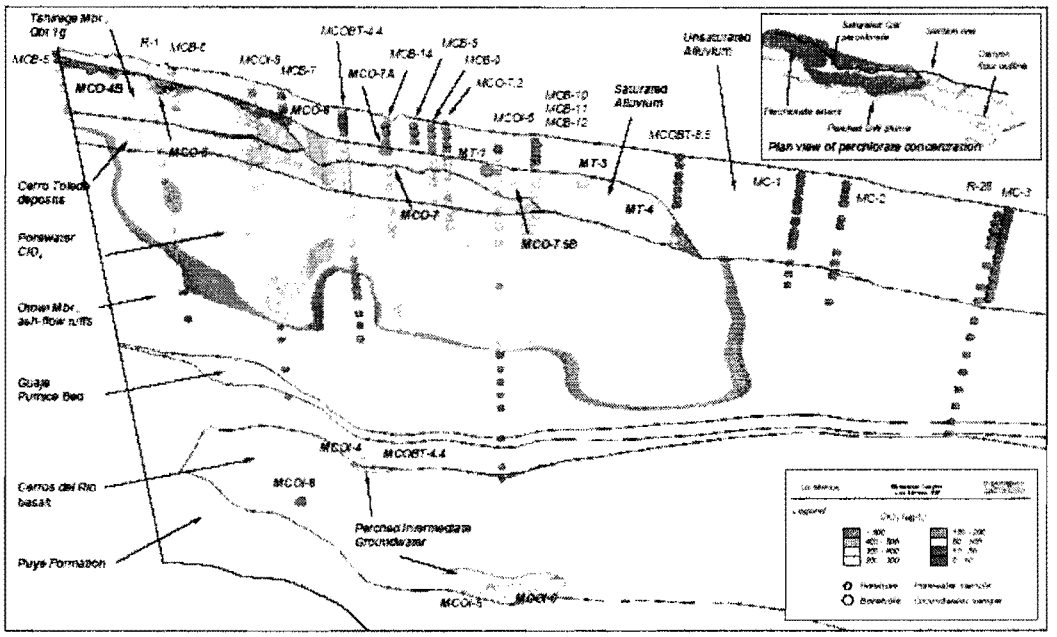
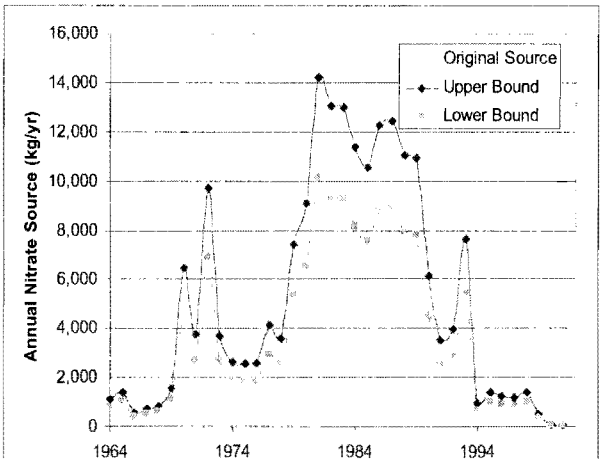
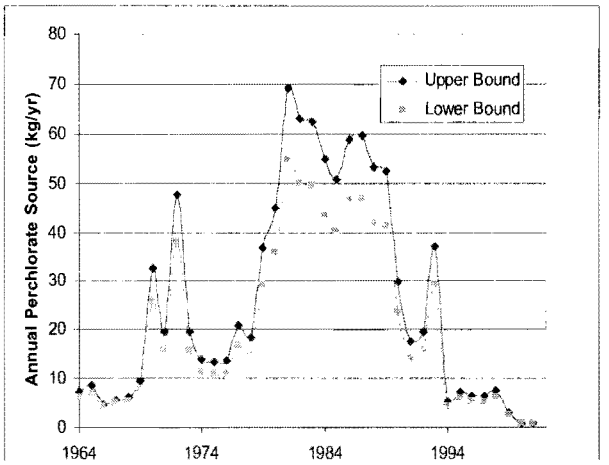


Figure 5. Estimated vadose-zone perchlorate distribution using data from 25 boreholes in Mortandad Canyon (LANL October 2006).



(a)



(b)

Figure 6. Nitrate and perchlorate release histories from the TA-50 RLWTF (LANL 2005).

(a) Original RLWTF nitrate source (NO_3 as N) and modeled source upper and lower bounds, assuming 2% and 30% denitrification

(b) Upper and lower bound perchlorate source derived from nitrate source, assuming 2% and 30% denitrification

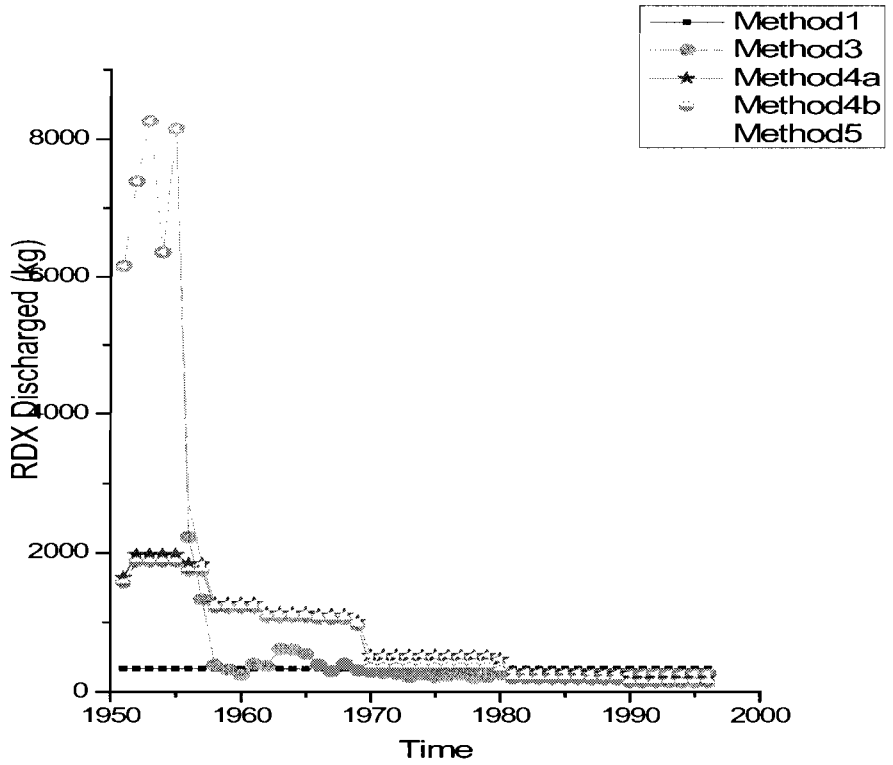


Figure 7. Time history of RDX discharges with time for the TA-16-260 outfall based on four different mass estimation techniques.

Table 1: Six key LANL outfalls and approximate contaminant quantity released

Source	Location Canyon (Watershed)	Operation	Period of Operation	Key Mobile Constituents Detected in Deep GW	Approximate Water Volumes Released (m^3)	Approximate Contaminant Quantity Released*	Approximate Key Radionuclide Released
Combined TA-1 & TA-45 Outfalls (SWMUs 01-002 and 45-001)	Acid Canyon (Pueblo Canyon)	Radioactive Waste Treatment	1944 - 1964	Tritium, perchlorate	600,000	Perchlorate – unknown Nitrate ~ 100,000 kg	Tritium ~ 58 Ci Sr-90 ~ 27 mCi Pu ~170 mCi
Omega West Reactor (SWMU 02-004[a])	Upper Los Alamos Canyon	Research and Molybdenum production	Possibly ca. 1970 - 1993	Tritium	2,000 to 4,000		Tritium 70 Ci (maximum)
SWMU 21-011(k)	DP Canyon (Los Alamos Canyon)	Industrial wastewater outfall	1952 - 1986	Tritium, perchlorate, nitrate	200,000	Perchlorate – unknown Nitrate > 20 kg	Tritium > 55 Ci Pu ~ 36 mCi Sr-90 ~ 5 mCi Cs-137 ~ 250 mCi Am-241 ?
TA-3 Power Plant (SWMU 03-045[h]-00), former TA-3 Wastewater Treatment Plant (legacy waste site 03-014(a)-99) and current sanitary wastewater system (SWWS)	Sandia Canyon	Cooling Towers and Sanitary Wastewater Treatment	1950 – present	Chromium (ca. 1956 – 1972); accidental tritium release with sanitary waste (ca. 1969 – 1986)	> 10,000,000 (~150,000 to 400,000 m^3/yr continuously since 1951)	Chromium ~ 26,000 to 105,000 kg	Tritium ~ 30 Ci
260 Outfall (SWMU 16-021[c]-99)	Canon de Valle (Water Canyon)	High Explosives machining	1951 - 1996	High explosives (RDX)	340,000 to 1,500,000	RDX 15,000 to 64,000 kg	None
TA-50 Outfall (NPDES Outfall 051)	Effluent Canyon (Mortandad Canyon)	Radioactive Wastewater Treatment	1963 – present	Tritium, nitrate, perchlorate	1,400,000	Perchlorate – 800 to 1200 kg Nitrate ~ 200,000 kg	Tritium ~800 Ci Sr-90 ~ 470 mCi Pu (239,240) ~ 0.2 Ci Pu (238) ~0.1 Ci Cs-137 ~ 2.1 Ci Am-241 ~ 0.2 Ci

*Note that tritium releases here are reported as original releases rather than decay-corrected current masses.
See [Rogers, 1998 (LA-13465-SR)] for tritium releases decay-corrected to 1997

Table 2. Key Material Disposal Areas radionuclide inventory estimates.

Material Disposal Area (MDA)	Location (Technical Area)	Period of Operation	Key Radionuclide Inventory*
A	21	1944-1978	Pu ~ 701 Ci Am ~ 1.5 Ci
B	21	1945-1952	Pu ~ 6.22 Ci Sr-90 ~ 0.285 Ci Cs ~ 0.005 Ci
T	21	1945-1986	Pu ~ 182 Ci Am ~ 3740 Ci U ~ 6.9 Ci
U	21	1948-1976	Unknown (Am, Cs, Pu, tritium, Sr, U)
V	21	1945-1961	Unknown (Am, Cs, Pu, Sr-90, U, tritium(?))
AB	49	1959-1961	Pu ~ 26200 Ci U ~ 0.246 Ci
C	50	1948-1974	Tritium ~ 20000 Ci Sr-90 ~ 21 Ci U ~ 25 Ci Pu ~ 26 Ci Am ~ 145 Ci
G	54	1957-1997 (parts remain active today)	Am ~ 2360 Ci Cs ~ 2810 Ci Tritium ~ 3610000 Ci Pu ~ 16000 Ci Sr-90 ~ 3500 Ci U ~ 124 Ci
H	54	1960-1986	Tritium ~ 240 Ci Pu ~ 0.0267 Ci U ~ 75.2 Ci

*Compiled from Sources:

[MDA G] Shuman, R. (URS Corp.), 2005, Radioactive Waste Inventory for Los Alamos National Laboratory Technical Area 54, Material Disposal Area G (Tables 48 and 49).

[MDA A] Design Basis Memorandum for MDA A, Los Alamos National Laboratory, Los Alamos, New Mexico, LA-UR-06-3793, RDL-NES-0012.

Memo from B. Ramsey and D. Satterwhite (LANL) to C. Steele (DOE), Nov. 21, 2003, Initial Categorization of Environmental Sites, RRES-DO:03-138.

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