13

Quality Assurance

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Introduction

Quality assurance (QA) is a system of activities and processes put in place to ensure that monitoring and measurement data meet user requirements and needs. Quality control (QC) consists of procedures used to verify that prescribed standards of performance in the monitoring and measurement process are attained. QA requirements for environmental monitoring of DOE facilities are mandated by DOE orders and guidance. DOE Order 5400.1 identifies QA requirements for radiological effluent and surveillance monitoring and specifies that a QA program consistent with DOE Order 5700.6 be established. The latter order sets forth policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that assure quality achievement in DOE programs. The DOE *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) requires that an Environmental Monitoring Plan be prepared that contains a QA section discussing the applicable elements of the American National Standards Institute / American Society of Mechanical Engineers (ANSI / ASME) NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME 1989).

LLNL conducted QA activities in 1997 at the Livermore site and Site 300 in accordance with a plan based on DOE Order 5700.6C (Pendexter 1993), which prescribes a risk-based, graded approach to QA. This process promotes the selective application of QA and management controls based on the risk associated with each activity, maximizing the effectiveness and efficiency in resource use.

LLNL environmental sampling is conducted according to procedures published in Appendix A of the LLNL Environmental Monitoring Plan (Tate et al. 1995). Environmental monitoring samples are analyzed by LLNL or commercial laboratories using EPA standard methods when available. When EPA standard methods are not available, custom analytical procedures, usually developed at LLNL, are used. The radiochemical methods used by LLNL laboratories are described in procedures unique to the laboratory performing the analyses. When analyses are performed by independent contractors, LLNL requires that their laboratories be certified by the State of California for the analyses performed for LLNL. In addition, LLNL requires all analytical laboratories to maintain adequate QA programs and documentation of methods.

13 Quality Assurance

Quality Assurance Activities

Nonconformance reporting and tracking is an LLNL quality assurance process aimed at ensuring that EPD activities meet EPD requirements. In 1997, Nonconformance Reports (NCRs) related to environmental monitoring were down from the 137 written in 1995 and the 106 written in 1996, to 87 written in 1997. As in previous years, most environmental monitoring NCRs covered missing samples. Unreliable air particulate sampling equipment has been a significant source of NCRs in the past; however, upgrades to that equipment over the last several years have resulted in a significant reduction in the number of NCRs. (See Chapter 5 for a more detailed account of equipment improvements.)

Half of the 24 NCRs attributed to analytical laboratories resulted from problems such as laboratory courier error or incorrect paperwork. These errors were corrected. Other problems such as missed holding times, late analytical results, and typographical errors on data reports accounted for the remaining NCRs attributable to the analytical laboratories. Many of these were corrected in the short-term by reanalysis or resampling, so required results were not lost. These problems continue to reappear, and they are addressed with the appropriate laboratory as they arise.

Of the 25 NCRs related to sewer monitoring, 13 could be attributed to failure to perform scheduled sampling, maintenance activities, or tasks performed incorrectly. The remaining 12 were related to minor equipment problems. Changes in the sewer monitoring procedures should minimize errors in the upcoming year.

Analytical Laboratories

In March of 1996, LLNL and Lawrence Berkeley National Laboratory (LBNL) began using new contracts with six off-site analytical laboratories (Garcia and MacQueen 1997).

All off-site analytical laboratories were audited in early 1997 and determined to be capable of fulfilling the requirements of the LLNL/LBNL analytical Statement of Work at that time. Areas for improvement were documented in the audit report for each laboratory and the EPD Assurance Manager and the Lead Auditor for each audit met with laboratory representatives to review those areas and begin to develop an implementation schedule for corrective actions.

During the summer of 1997, one of the laboratories experienced internal problems of such severity that its parent company eventually declared bankruptcy and closed the

laboratory in January 1998. The closure had no impact on LLNL environmental monitoring.

Participation in Laboratory Intercomparison Studies

The LLNL Chemistry and Materials Science Environmental Services Environmental Monitoring Radiation Laboratory (CES EMRL) and the Hazards Control Department's Analytical Laboratory (HCAL) participated in both the Environmental Protection Agency's (EPA) Environmental Monitoring Systems Laboratory (EMSL) intercomparison studies program and the DOE Environmental Monitoring Laboratory (EML) intercomparison studies program in 1997. A review of the EMSL study indicates that 37 of 37 analyses reported by CES and 10 of 10 analyses reported by HCAL fell within established acceptance control limits. For the EML studies, 82 of 84 reported by CES and 10 of 10 results reported by HCAL fell within the established acceptance control limits.

The HCAL also participated in four EPA Water Pollution and Water Supply intercomparison studies for metals during 1997. Review of these results shows that values for 32 of 34 samples fell within established acceptance control limits.

The intercomparison study results, as well as the follow-up explanation and response for data that fell outside the acceptance control limits are presented in the Data Supplement. Contract laboratories are also required to participate in laboratory intercomparison programs; however, permission to publish their results for comparison purposes was not granted for 1996.

The potential effects of unacceptable intercomparison study results on routine data have not been fully determined or evaluated. A joint EPD/CES performance evaluation committee has been formed to create a systematic process for evaluating laboratory performance using traceable standards. A method for evaluating the results of intercomparison studies will be developed by that committee.

Duplicate Analyses

Duplicate or collocated samples are distinct samples of the same matrix collected as closely as possible to the same point in space and time, and are intended to be identical in all respects. Collocated samples processed and analyzed by the same organization provide intralaboratory precision information for the entire measurement system, including sample acquisition, homogeneity, handling, shipping, storage, preparation,

and analysis. Collocated samples processed and analyzed by different organizations provide interlaboratory precision information for the entire measurement system (U.S. Environmental Protection Agency 1987). Collocated samples may also be used to identify errors—for example, mislabeled samples and data entry errors.

Tables 13-1 through **13-3** present statistical data for collocated sample pairs, grouped by sample matrix and analyte. Samples from both the Livermore site and Site 300 are included. **Tables 13-1** and **13-2** contain data pairs in which both values are above the detection limit, and radiological results for which an estimated activity was reported. The tables exclude radiological values for which only a minimum detectable activity was reported. In addition, **Table 13-2** excludes radiological results for which the reported value is negative. **Table 13-3** contains data pairs in which either or both values are below the detection limit.

If there were more than eight data pairs with both results above the detection limit, precision and regression analyses were performed; the results are presented in **Table 13-1**. Precision is measured by the percent relative standard deviation (%RSD); see the EPA *Data Quality Objectives for Remedial Response Activities: Development Process*, Section 4.6 (U.S. Environmental Protection Agency 1987).

Acceptable values for %RSD vary greatly with matrix, analyte, and analytical method; however, values above 30% are common. The results for %RSD given in **Table 13-1** are the 75th percentile of the individual precision values. Regression analysis consists of fitting a straight line to the collocated sample pairs. Good agreement is indicated when the data lie close to a line with slope equal to one and intercept equal to zero, as illustrated in **Figure 13-1**. Allowing for normal analytical variation, the slope of the fitted line should be between 0.7 and 1.3, and the absolute value of the intercept should be less than the detection limit. The coefficient of determination (r^2) should be >0.8.

If there are eight or fewer data pairs with both results above the detection limit, the ratios of the individual duplicate sample pairs are averaged; the average, minimum, and maximum ratios for selected analytes are given in **Table 13-2**. The mean ratio should be between 0.7 and 1.3.

If one of the results in a pair is below the detection limit, then the other result should be less than two times the detection limit. **Table 13-3** identifies the sample media and analytes for which at least one pair failed this criterion. Analytes with fewer than four pairs total are omitted from the table.

Table 13-1. Quality assurance duplicate sampling. Summary statistics for analytes with more than eight pairs in which both results were above the detection limit.

Matrix	Analyte	N[a]	%RSD[b]	Slope	r^2[c]	Intercept
Air	Beryllium	14	22.7	0.903	0.98	0.337 (pg/m^3)
	Gross alpha[d]	104	73.9	0.481	0.22	2.267 (pCi/L)
	Gross beta	104	14.3	0.972	0.92	5.045 (pCi/L)
	Plutonium-239[d,e]	11	75.7	0.126	0.07	1.79×10^{-10} (pCi/L)
	Uranium-235 by mass	11	6.11	0.949	0.98	3.53 (µg/m^3)
	Uranium-238 by mass	11	8.77	0.953	0.98	4.529 (µg/m^3)
	Tritium	34	17.7	1.12	0.94	–0.09 (pCi/m^3) (air)
Radiation dose	Radiation dose	29	2.74	0.839	0.84	2.56 (mrem)
Ground water	Arsenic	22	10.3	0.947	0.99	0.000 (mg/L)
	Barium	17	4.29	0.966	1.0	0.000 (mg/L)
	Chloride[e]	11	1.31	1.05	0.69	18.8 (mg/L)
	Chromium	13	10.1	0.845	0.97	0.000 (mg/L)
	Fluoride	11	5.66	0.994	0.96	0.018 (mg/L)
	Gross alpha[d]	22	58.7	0.874	0.77	0.867 (pCi/L)
	Gross beta[d]	22	16.4	0.755	0.64	1.89 (pCi/L)
	Nickel	9	7.44	0.951	0.99	0.000 (mg/L)
	Nitrate (as N)	12	6.22	1.06	0.99	–0.39 (mg/L)
	Nitrate (as NO_3)	25	2.98	1.06	0.99	–1.47 (mg/)L
	Orthophosphate	9	6.73	0.985	0.92	0.002 (mg/)L
	Radium-226	10		1.20	0.89	0.051 (pCi)/L
	Sodium	9	4.56	1.04	0.95	–3.09 (mg/L)
	Specific conductance	10	0.804	0.907	0.96	119 (µmho/cm)
	Sulfate[e]	11	6.40	0.836	0.68	50.0 (mg/L)
	Uranium-234 and uranium-233	19	8.09	0.929	0.99	0.160 (pCi/L)
	Uranium-235 and uranium-236[d]	19	28.3	0.666	0.89	0.018 (pCi/L)
	Uranium-238	19	12.0	1.01	1.0	0.029 (pCi/L)
	Vanadium	9	3.75	1.01	1.0	–0.00 (mg/L)
	pH[e]	10	0.552	0.756	0.34	1.90 (pH units)
Sewer	Gross alpha[d]	53	89.4	0.354	0.12	2.00 (pCi/L)
	Gross beta	53	22.0	0.726	0.95	5.27 (pCi/L)
	Tritium	53	93.2	0.918	0.83	24.7 (pCi/L)

a Number of duplicate pairs included in regression analysis.

b 75th percentile of percent relative standard deviation (%RSD), where %RSD = $\left(\frac{200}{\sqrt{2}}\right)\left(\frac{|x_1 - x_1|}{x_1 + x_2}\right)$ and x_1 and x_2 are the reported concentrations of each routine-duplicate pair.

c Coefficient of determination.

d Outside acceptable range of slope or r^2 due to variability.

e Outside acceptable range of slope or r^2 due to outliers.

Table 13-2. Quality assurance duplicate sampling. Summary statistics for selected analytes with eight or fewer pairs in which both results were above the detection limit.

Media	Analyte	N[(a)]	Mean ratio	Minimum ratio	Maximum ratio
Aqueous	Gross alpha	1	14.0	14.0	14.0
	Gross beta	1	1.4	1.4	1.4
	Tritium	1	0.84	0.84	0.84
Ground water	Thorium-232	1	0.23	0.23	0.23
	Trichloroethene	8	1.3	0.87	3.5
	Tritium	8	0.99	0.53	1.3
Rain	Tritium	2	1.0	0.89	1.1
Runoff (from rain)	Gross alpha	5	2.5	0.70	6.2
	Gross beta	5	0.96	0.68	1.4
Soil	Beryllium	1	1.1	1.1	1.1
	Cesium-137	2	0.89	0.82	0.95
	Plutonium-239/240	2	0.99	0.84	1.1
Vegetation	Tritium, per gram dry weight	6	1.1	0.61	1.9

a Number of data pairs.

b Outside acceptable range of 0.7–1.3, for mean ratio.

Collocated sample comparisons are more variable when the members of the pair are analyzed by different methods or with different criteria for analytical precision. For example, radiological analyses using different counting times will have different amounts of variability.

These analyses show generally good agreement between routine samples and quality assurance duplicates: approximately 82% of the pairs have a precision better than 30%. Data sets not meeting our precision criteria generally fall into one of two categories. The first category, outliers, can occur because of data transcription errors, measurement errors, or real but anomalous results. Of 31 data sets reported in **Table 13-1**, four did not meet the criterion for acceptability because of outliers. **Figure 13-2** illustrates a set of collocated pairs with one outlier. The other category of results that does not meet the criterion for acceptability consists of data sets in which there is a lot of scatter. This tends to be typical of measurements at extremely low concentrations as illustrated in **Figure 13-3**.

Table 13-3. Quality assurance duplicate sampling. Summary statistics for analytes with at least four pairs in which one or both results were below the detection limit.

Medium	Analyte	Number of inconsistent pairs	Number of pairs	Percent of inconsistent pairs
Air	Tritium	1	17	5.8
	Tritium (H_2O)	1	17	5.8
Ground water	Aluminum	1	16	6.3
	Ammonia nitrogen (as N)	1	5	20
	Copper	2	27	7.4
	Di-*n*-octylphthalate	1	12	8.3
	Iron	2	13	15.4
	Nitrite (as N)	1	11	9.1
	Selenium	1	13	7.7
	TNT	1	7	14.3
	Zinc	1	29	3.4
Storm water	Iron	3	4	75
	Tritium	1	5	20
Sewer	Chromium	2	5	40
	Silver	1	6	16.7
	Trichlorofluoromethane	1	4	25
	o-Cresol	1	4	25

Low concentrations of radionuclides on particulates in air highlight this effect even more because one or two radionuclide-containing particles on an air filter can significantly impact results. Another cause of high variability is sampling and analytical methodology. Analyses of total organic carbon and total organic halides in water are particularly difficult to control. Of the 31 data sets in **Table 13-1**, six show sufficient variability in results to make them fall outside of the acceptable range. Some data sets exhibit both outliers and high variability.

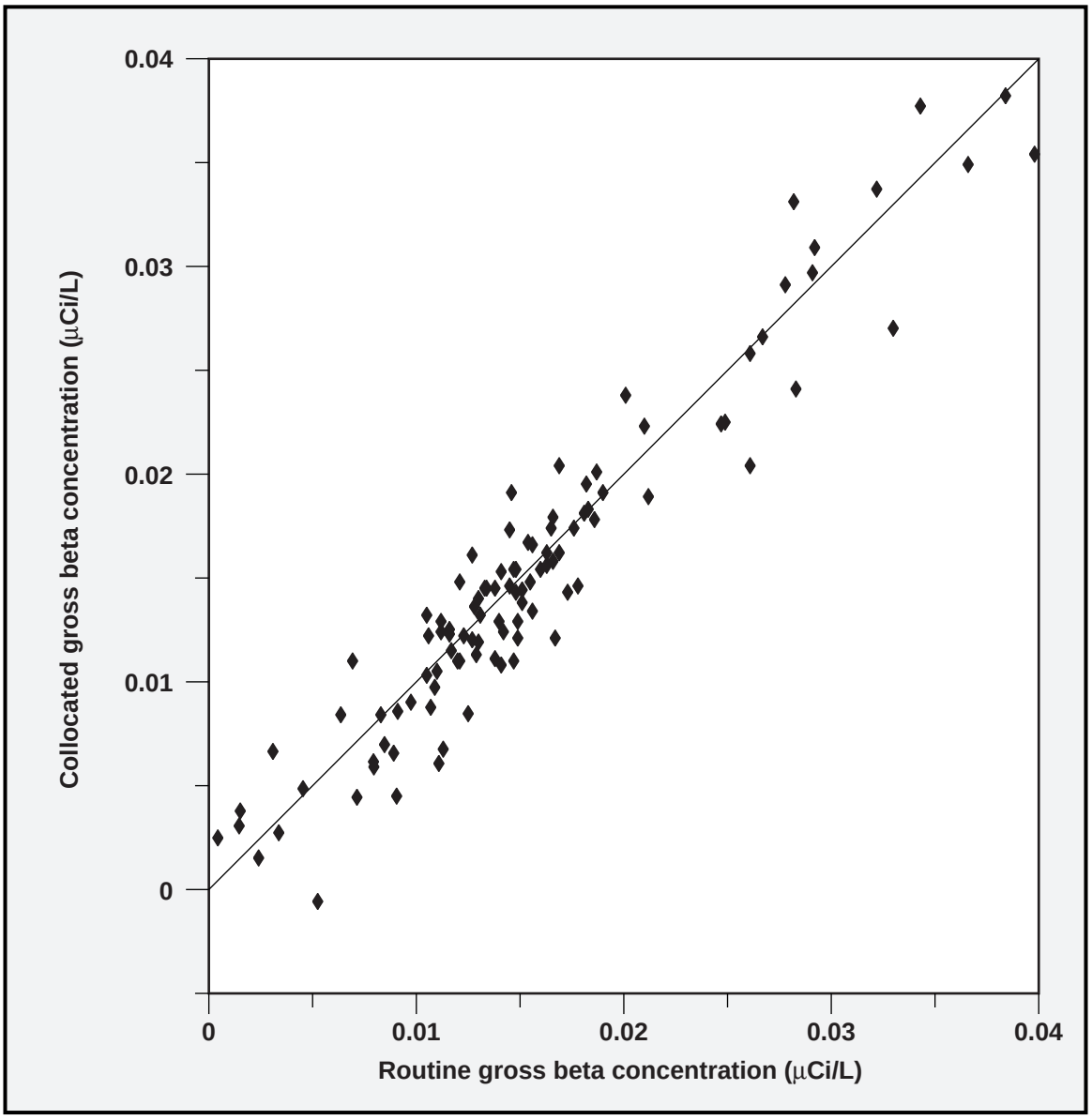

Figure 13-1. Gross beta concentrations from collected samples. These data lie close to a line with slope equal to one and an intercept equal to zero.

Deviations and Changes to the Sampling Program

The sections that follow summarize changes to the environmental sampling effort made during 1997, deviations from planned environmental sampling, and omissions of data expected from regularly scheduled samples.

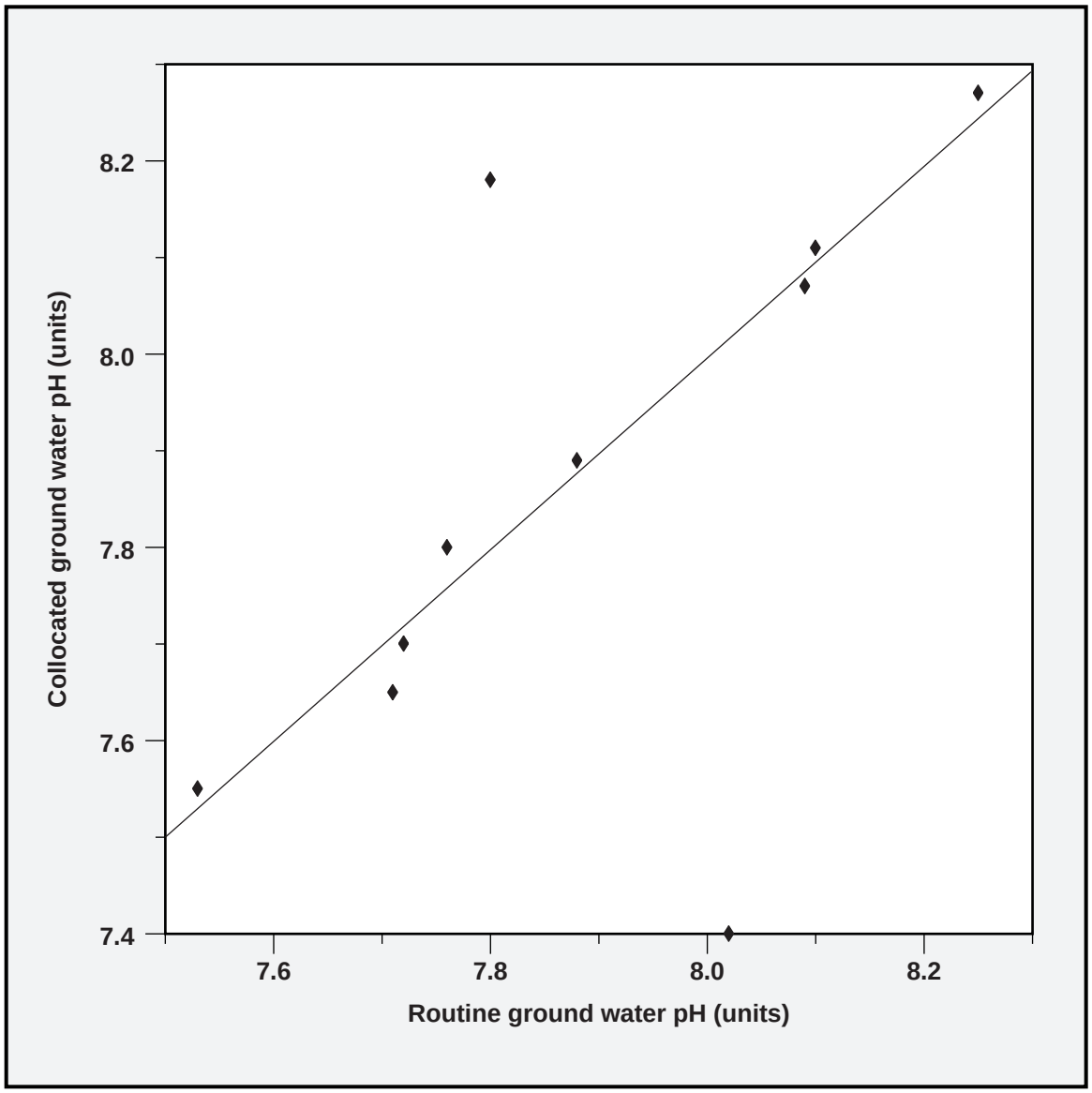

Figure 13-2. Ground water pH from collected samples showing one outlier.

Changes to Environmental Monitoring Networks

Changes that were made to environmental monitoring networks in 1997 are summarized in **Table 13-4**. The air particulate network was split into two separate networks—one for monitoring radiological parameters and the other for monitoring beryllium—in 1997. This change was made because of the need to use different type of filters for collecting beryllium and radiological samples. Livermore Valley air particulate monitoring locations L-ALTA and L-RRCH were abandoned in 1997 because agreements for

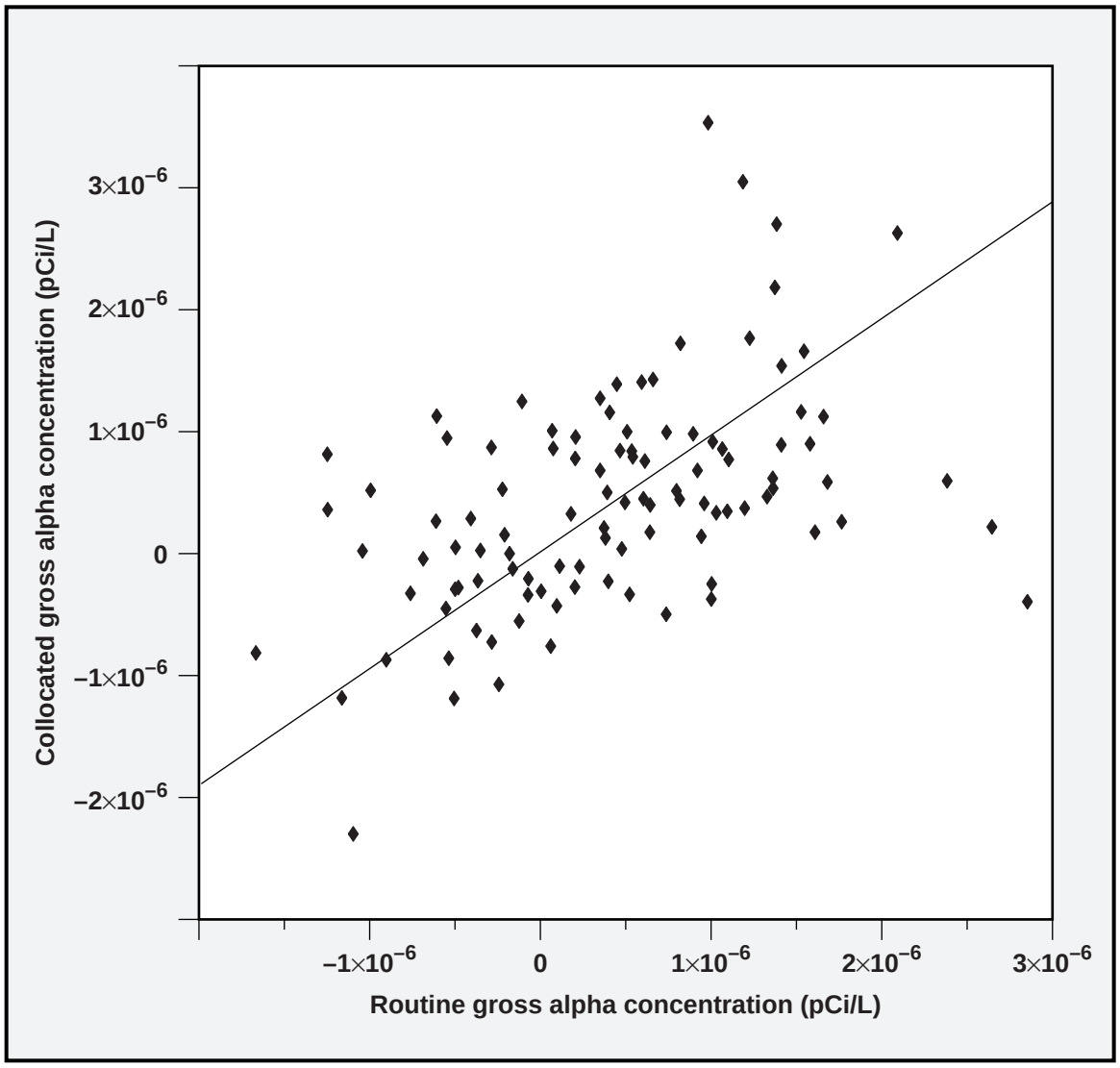

Figure 13-3. Gross alpha concentration from collected samples showing data with a lot of scatter.

continued access to the property could not be reached with the landowners. Location L-RRCH was replaced by L-CHUR, also on Vasco Road, north of LLNL. Location L-ALTA will be replaced by a new location, L-AMON, in 1998. Initiation of sampling at L-AMON was delayed due to difficulties associated with supplying power to that location. One location change was made to the Site 300 air particulate monitoring network prior to 1997—location 3-LIN was replaced by 3-PRIM. The new location better represents the sitewide maximally exposed individual and thus improves LLNL's ability to evaluate the dose to the public. In addition, off-road four-wheel drive access to 3-LIN was often denied for safety reasons; the new location should be more consistently available.

Table 13-4. Changes to environmental monitoring networks in 1997.

Environmental medium	Livermore site	Site 300
Air particulate	Abandoned location L-ALTA, 5/97; replaced location L-RRCH with location L-CHUR, 6/97	Replaced location 3-LIN with 3-PRIM prior to 1997
	Split into radiological air particulate and air particulate beryllium networks	Split into radiological air particulate and air particulate beryllium networks
Air tritium	Abandoned location L-ALTA, 5/97	Added location L-PRIM
Soil	Replaced location L-ALTA with L-AMON; replaced location L-RRCH with L-CHUR. Abandoned locations L-CAFE, L-ERCH.	No changes
Arroyo sediment	Added location L-ALPE	Not sampled
Vegetation	No changes	No changes
Wine	No changes	Not sampled
Rain	Added special study (on-site locations only)	No changes
Storm water runoff	Expanded pesticides monitoring, initiated special metals study	No changes
Drainage Retention Basin	No changes	Not sampled
Other surface water	Monthly pool sampling for tritium reduced to quarterly; eliminated pool sampling for lead	Not sampled
Ground water	Added several wells, W-204, W-363, W-119, W-906, W-1303, W-1308, W-594, W-593, W-007, W-226, W-306, and W-307, to monitor possible leachate from disposal sites.	No changes
Sewage	No changes	See WDR-248
WDR-248 Networks	Not applicable	No changes
Thermoluminescent dosimeters	Minor changes to three locations	No changes
Cooling towers	Not sampled	No changes

The air tritium network also abandoned location L-ALTA in 1997. This will be replaced by L-AMON in 1998. Routine air tritium monitoring at one Site 300 location was also performed for the first time in 1997 in response to the results of previously conducted special studies.

Minor location changes were also made to the soil and arroyo sediment monitoring networks in 1997. Soil sampling locations L-ALTA and L-RRCH were abandoned for the same reason air sampling was stopped there. Since electrical power is not required for soil sampling, these locations were replaced by L-AMON and L-CHUR in 1997. Soil

sampling at locations L-CAFE and L-ERCH was also abandoned in 1997. L-ERCH could no longer be accessed due to difficulties in obtaining permission from the landowner; L-CAFE was dropped because of the unavailability of suitable soil for sampling at that location. Location L-ALPE was reinstated as part of the arroyo sediment network because it is a separate influent location to the Livermore site at which storm water runoff is also sampled. This location had been abandoned previously because the responsible environmental analyst was not aware it was a separate influent location.

Rain monitoring included special sampling of onsite locations for five storms in November. These additional storms were sampled because of an unexpectedly high value for tritium in an on-site runoff sample. Since storm water runoff cannot be resampled, expanded monitoring of subsequent storms is often used to validate or invalidate unexplained or unusual results.

Monitoring of storm water runoff was modified slightly in 1997 to specifically target pesticides used on site. Initially, these pesticides were only sampled at locations L-ASW and L-WPDC; monitoring was expanded to include the entire storm water runoff network based on the results of those samples. Metals analysis of storm water runoff was expanded to include both filtered and unfiltered samples beginning in November 1997. This source identification study will provide data that will enable us to determine what proportion of the metals detected in runoff is attributable to naturally occurring sediments and define the contributions of the aqueous and sediment fractions to the total reported values. This study will be completed in 1998 and a full discussion of the results will appear in the 1998 Annual Environmental Report.

In other surface water monitoring, sampling of the LLNL pool for tritium was reduced from monthly to quarterly and sampling of the pool for lead was eliminated after the second quarter. These reductions were made based upon a review of historical data.

Sampling locations for three Livermore Valley thermoluminescent dosimeters (TLDs) were changed slightly due to construction in the area. Sampling locations were moved from fences that had been removed to other nearby fences.

The LLNL environmental monitoring program uses alphanumeric location designator codes to define sampling locations. Tables 13-1 to 13-3 in Chapter 13 of the Data Supplement decode these sampling location designators and provide a cross-reference between current designators and those used in previous years. Changes made in 1997 are noted on those tables.

Explanation of Missing Samples

Planned samples and actual samples collected and analyzed in 1997 are summarized in **Table 13-5**. Air particulate sample loss was due to equipment failure, electrical problems, and access restrictions. Air tritium sample loss was due to a broken flask, equipment failure, electrical problems, and access restrictions. Missing arroyo sediment samples could not be taken because one sampling location was flooded with over four feet of water during the sampling period. Missing Livermore site rain samples were overlooked by the sampling technologist and not collected. Site 300 rain samples were not taken in February, April, and October due to lack of rainfall and are not counted as missing samples. Storm water runoff samples were missed at Site 300 because one location could not be accessed during the storm that was sampled and there was no flow at two other locations. The monthly Drainage Retention Basin (DRB) sample was not taken in August. Missing field measurements for dissolved oxygen and temperature in the DRB were due to equipment malfunction; several turbidity measurements in the DRB were not taken due to oversight by the sampling technologists. Analysis for radium-226 and radium-228 was omitted for five samples from the Livermore ground water network when the laboratory substituted a different analytical method for the one that was requested without consulting the environmental analyst. Two Site 300 ground water samples were inadvertently missed the remaining 131 missing samples were due to mechanical problems with pumps or barcads or access restriction due to construction in the area. Two planned samples from Livermore valley surface wells were not supplied and could not be analyzed. These wells are not sampled by LLNL directly making it difficult to consistently achieve 100% completeness for this network. Two daily sewage samples at Building 196 were lost in December due to equipment failure. In the WDR sewage ponds wastewater network, one sample and its duplicate were not analyzed because the analytical laboratory missed the holding time. Two TLDs from the Site 300 network and six from the Livermore networks disappeared during 1997, probably due to cows or vandalism. The remaining TLDs that were lost from the Livermore networks were due to construction in the area that led to the removal of fences and the attached TLDs; several sampling locations were permanently changed as a result. Five Site 300 cooling tower samples were inadvertently omitted due to technologist oversight.

Table 13-5. Sampling completeness in 1997, Livermore site and Site 300.

Environmental medium	Number of samples planned	Number of samples analyzed	Completeness (%)
Air particulate (Livermore)			
Radiological parameters	1224	1195	97.6
Beryllium	96	96	100
Air particulate (Site 300)			
Radiological parameters	672	665	99.0
Beryllium	60	60	100
Air tritium			
Livermore	528	524	99.2
Site 300	26	24	92.3
Soil			
Livermore	42	42	100
Site 300	30	30	100
Arroyo sediment (Livermore only)	32	28	87.5
Vegetation			
Livermore	32	32	100
Site 300	68	68	100
Wine	25	25	100
Rain			
Livermore	86	83	96.5
Site 300	4	4	100
Storm water runoff			
Livermore	367	367	100
Site 300	73	48	65.8
Drainage Retention Basin			
Field measurements	156	110	75.0
Samples	104	99	95.2
Other surface water (Livermore only)	64	64	100
Ground water			
Livermore	698	687	98.4
Site 300	3975	3842	96.6
Livermore Valley wells	26	24	92.3

Table 13-5. Sampling completeness in 1997, Livermore site and Site 300.

Environmental medium	Number of samples planned	Number of samples analyzed	Completeness (%)
Sewage			
B196	913	909	99.6
C196	374	374	100
LWRP effluent	128	128	100
Digester sludge	376	376	100
WDR-96-248			
Surface impoundments wastewater	69	69	100
Surface impoundments ground water	272	272	100
Sewage ponds wastewater	30	28	93.3
Sewage ponds ground water	120	120	100
Thermoluminescent dosimeters			
Livermore	172	157	91.3
Site 300	72	70	97.2
Cooling towers (Site 300 only)	84	79	94.0

Statistical Methods

Statistical methods used in this report have been implemented pursuant to the *Environmental Monitoring Plan* (Tate et al. 1995). These methods reduce the large volumes of monitoring data to summary concentration estimates that are suitable for both temporal and spatial comparisons. Attention is given to estimating accuracy, bias, and precision of all data.

Data review and analyses are conducted in accordance with the *Environmental Monitoring Plan* and the Environmental Monitoring Section's Data Analysis Procedure. These documents contain detailed information regarding the acceptability of data and the procedures that are followed for the identification, notification, and correction of suspect data.

Radiological Data

The precision of radiological analytical results is displayed in the Data Supplement data tables as the 2σ counting error. The counting errors are not used in any summary

statistic calculations. Any radiological result exhibiting a 2σ counting error greater than or equal to 100% is considered to be indistinguishable from zero. The reported concentration is derived from the number of sample counts minus the number of background counts. A sample with a low or zero concentration may therefore be reported to have a negative value; such results are reported in the tables and used in the calculation of summary statistics and statistical comparisons. Some analytical laboratory reports provide a minimum detectable activity rather than a reported value when the radiological result is below the detection criterion. In this case, the result is presented in the tables with a less-than symbol (<) to indicate its status.

Nonradiological Data

Nonradiological data that are reported as being below the analytical detection limit also are displayed in the tables with a less-than symbol. The actual detection limit values are used in the calculation of summary statistics as explained below.

Statistical Comparisons

Standard comparison techniques (such as regression, t-tests, and analysis of variance) have been used where appropriate to determine the statistical significance of trends or differences between means. All such tests of significance have been performed at the 0.05 level. When such a comparison is made, it is explicitly stated in the text as being "statistically significant" or "not statistically significant." Other uses of the word "significant" in the text do not imply that statistical tests have been performed. These uses instead relate to the concept of practical significance and are based on professional judgment.

Summary Statistics

Determinations of measures of central tendency and associated measures of dispersion are calculated according to the *Environmental Monitoring Plan* (Tate et al. 1995). For data sets not containing values below the detection criterion, the measures of central tendency and dispersion are the median and interquartile range (IQR). The IQR is the range that encompasses the middle 50% of the data set. Radiological data sets that include values less than zero may have an IQR greater than the median.

For data sets with one or more, but fewer than one half, values below the detection criterion, the measure of central tendency is the median. If the values of the detection limits and the number of values below the detection limit permit (determined on a case-by-case basis), dispersion is reported as the IQR. Otherwise, no measure of dispersion is reported. Statistics are calculated using the reported detection limit value for nonradiological data or the reported value for radiological data.

For data sets with one half or more of the values below the detection criterion, the central tendency is reported as less than the median value. Dispersion is not reported.

Radiation Units

Data for 1997 have been reported in Système Internationale (SI) units to conform with standard scientific practices and federal law. Values in the text are reported in becquerels (Bq) and millisieverts (mSv); equivalent values in picocuries (pCi) and millirems (mrem) are given in parentheses.

Quality Assurance Process for the Environmental Report

Unlike the preceding discussion, which focused on standards of accuracy and precision in data acquisition and reporting, a discussion of quality assurance / quality control procedures for a technical publication per se, must deal with how to retain content accuracy through the publication process. Because publication of a large, data-rich document like this site annual *Environmental Report* involves many operations and many people, the chances for introducing errors are great. At the same time, ensuring quality is more difficult because a publication is less amenable to the statistical processes used in standard quality assurance methods.

The QA procedure we used concentrated on the tables and figures in the report and enlisted the chapter authors and participating analysts to check the accuracy of sections other than those they had authored. In 1997, the 75 illustrations and 68 tables in Volume 1 (now called the main volume) and the 121 tables in Volume 2 (now called the Data Supplement) were checked by 27 authors, contributors, and a few summer students. Checkers were assigned illustrations and tables and given a copy of each item they were to check along with a quality control form to fill out as they checked the item. Items to be checked included figure captions and table titles for clarity and accuracy, figure labels and table headings, units, significant figures, and consistency with text. When checking numerical data, checkers randomly selected 10% of the data and compared it to values in the master database. If all 10% agreed with the database, further checking was deemed unnecessary. If there was disagreement in the data, the

checker compared another 10% of the data with the database values. If more errors were found, the checker had then to verify every piece of data in the table or illustration.

Completed quality control forms and the corrected illustrations or tables were returned to the report editors, who were responsible for ensuring that changes, with the agreement of the original contributor, were made. This quality assurance check resulted in over 100 changes being made to the draft document. These included corrections to numerical data in text and tables, slight adjustments to sampling locations on maps, corrections to footnotes in tables, and corrections to figure captions and table titles.